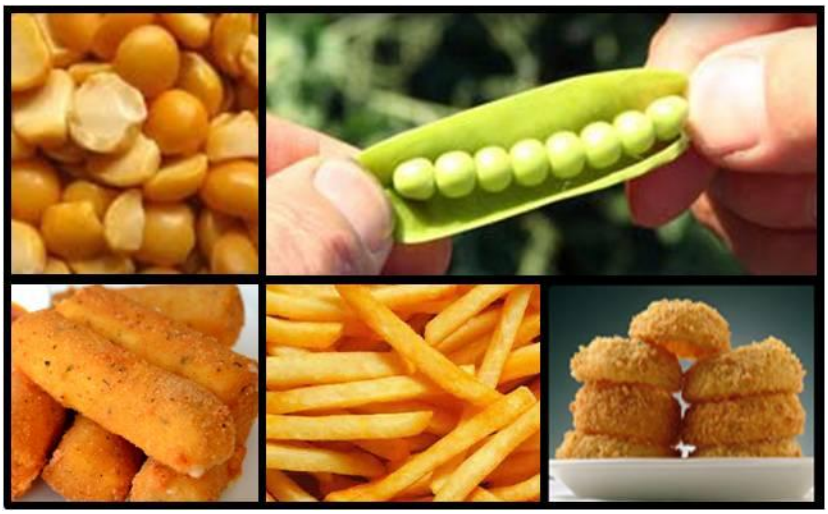
Evaluation of Pea Starch in the Development of Functional Coatings Using Pea Ingredients for French Fry, Mozzarella Stick, and Onion Ring Applications



Food Development Centre
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FOOD DEVELOPMENT CENTRE
Growing Opportunities in Food

July 16 , 2012

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Evaluation of Pea Starch in the Development of Functional Coatings Using Pea Ingredients for French Fry, Mozzarella Stick, and Onion Ring Applications

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Final Report

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EXECUTIVE SUMMARY

Yellow field peas are one of the major pulse crops grown in Canada. They provide low glycemic index, gluten-free food ingredients that are high in both protein and fibre but low in fat. Both wet and dry milled pea fractions (starch, protein, and hull fibre) and pea flour have unique functional and nutritional properties. These beneficial ingredients are currently underutilized by food manufacturers with use and sales of pea starch being especially low.

The objective of this project was to evaluate the suitability of pea starch and other yellow pea ingredients as replacements for traditional ingredients such as corn, wheat, and soy flours, corn starch, wheat gluten, whey, gums, and colour in coatings for French fry, mozzarella stick, and onion ring applications. Functional, sensory, nutritional, and economic aspects of utilizing pea ingredients were assessed. Both wet and dry milled pea ingredients were evaluated when possible. This research was carried out in collaboration with Newly Weds Foods and Canada's three major pea processors (Best Cooking Pulses, Nutri-Pea Ltd., and Parrheim Foods) to ensure industry relevance of the findings. Financial support was provided by the Alberta Crop Industry Development Fund Ltd., Alberta Pulse Growers Commission, Pulse Canada, Manitoba Pulse Growers Association, and Parrheim Foods.

This final report summarizes the research findings and provides recommendations on utilization of pea starch and other pea ingredients in French fry, mozzarella stick, and onion ring coatings. To facilitate easy distribution to appropriate food industry sectors, the report is divided into sections by product application. Complete replacement of modified corn starch with native pea starch was possible with minimal impact on processing and product quality. Starch replacement resulted in more natural coated food products with a slight coating cost increase due to the higher price of pea starch. In conjunction with pea starch, pea flour and hull fibre were also successfully used as

replacements for traditional wheat, corn, and soy flours and other functional ingredients like gums, wheat gluten, and caramel colour to create allergen free products with a cleaner label and potential for gluten-free status. Overall, pea-containing coated prototypes were more golden in colour and were higher in fibre and protein than coated prototypes containing traditional ingredients. A small cost savings of $0.01 - 0.03 CDN/lb was achieved by replacing traditional ingredients with pea ingredients in the hydrated coating systems of French fries, mozzarella sticks and onion rings.

This study has shown that pea ingredients can successfully replace traditional starch, flour, and minor functional ingredients in coating systems to produce desirable food products that address consumers' nutritional and health concerns. These research findings provide Canadian pea growers and processors with a new marketing tool and food processors with new information to facilitate use of pea ingredients in battered and breaded food systems; thus, ultimately increasing yellow pea utilization.

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The information presented in this report is correct to the best of the authors' knowledge. World Wide Web sites that have been referred to may or may not contain the information at a later date. Any opinions, findings, conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of FDC. The information contained in this report is intended to provide a general guideline only. The authors disclaim all responsibility for any detrimental effects resulting from the way in which the information is used.

Table of Contents

EXECUTIVE SUMMARY .... **II**

ACKNOWLEDGEMENT AND DISCLAIMER .... **IV**

1.0. INTRODUCTION **10**

2.0. FRENCH FRIES **13**

2.1. EXPERIMENTAL DESIGN 13
2.2. MATERIALS 14
2.2.1. Potatoes *14*
2.2.2. Coating system *14*
2.3. SAMPLE PREPARATION 16
2.4. TEST METHODS 18
2.4.1. Sensory evaluation *18*
2.4.2. Nutritional analysis *19*
2.4.3. Weight loss *19*
2.4.4. Instrumental texture *19*
2.4.5. Instrumental colour *20*
2.4.6. Freeze-thaw stability *20*
2.5. STATISTICAL ANALYSIS 21
2.6. RESULTS & DISCUSSION 21
2.6.1. Starch replacement *21*
A. Physiochemical characteristics *21*
B. Sensory evaluation *23*
C. Objective results *25*
2.6.2. Development of optimized French fry coating with pea ingredients *27*
A. Physiochemical characteristics *32*
B. Sensory evaluation *34*
C. Objective tests *36*
2.7. NUTRITIONAL COMPOSITION 39
2.8. COST IMPLICATIONS 41
2.9. CONCLUSIONS – FRENCH FRY 43
2.10. OPPORTUNITIES & CHALLENGES – FRENCH FRIES 45

3.0. MOZZARELLA STICKS **46**

3.1. EXPERIMENTAL DESIGN 46
3.2. MATERIALS 47
3.2.1. Mozzarella sticks *47*
3.3. SAMPLE PREPARATION 50
3.4. TEST METHODS 51
3.4.1. Sensory evaluation *51*
3.4.2. Nutritional analysis *51*
3.4.3. Weight loss *52*
3.4.4. Moisture content *52*
3.4.5. Instrumental texture *53*
3.4.6. Instrumental colour *53*
3.4.7. Freeze-thaw stability *54*
3.5. STATISTICAL ANALYSIS 55
3.6. RESULTS & DISCUSSION 55
3.6.1. Starch replacement *55*
A. Physiochemical characteristics *55*
B. Sensory evaluation *58*
C. Objective results *61*
3.6.2. Pea fraction optimization *63*

A. Physiochemical characteristics ... 67
B. Sensory evaluation ... 68
C. Objective results ... 70
3.7. Nutritional composition ... 73
3.8. Cost implications ... 77
3.9. Conclusions – Mozzarella sticks ... 78
3.10. Opportunities & challenges – Mozzarella sticks ... 80
4.0. ONION RINGS ... 82
4.1. Experimental Design ... 82
4.2. Materials ... 83
4.2.1. Onions ... 83
4.2.2. Coating system ... 83
4.3. SAMPLE PREPARATION ... 85
4.4. Test methods ... 86
4.4.1. Sensory evaluation ... 86
4.4.2. Nutritional analysis ... 86
4.4.3. Weight loss ... 87
4.4.4. Moisture content ... 87
4.4.5. Instrumental texture ... 88
4.4.6. Instrumental colour ... 88
4.4.7. Freeze-thaw stability ... 89
4.5. Statistical analysis ... 89
4.6. Results & discussion ... 90
4.6.1. Starch replacement ... 90
A. Physiochemical characteristics ... 90
B. Sensory evaluation ... 92
C. Objective results ... 94
4.6.2. Pea fraction optimization ... 95
A. Physiochemical characteristics ... 99
B. Sensory evaluation ... 100
C. Objective results ... 103
4.7. Nutritional composition ... 104
4.8. Cost implications ... 108
4.9. Conclusions – Onion rings ... 109
4.10. Opportunities & challenges – Onion rings ... 111
5.0. OVERALL CONCLUSIONS ... 112
6.0. FURTHER RESEARCH ... 115
7.0. PROJECT IMPACT & INDUSTRY INTERACTION ... 116
8.0. FINANCIAL UPDATE ... 119
9.0. REFERENCES ... 119
10.0. PROJECT PARTNERS ... 121
APPENDIX A ... 123
APPENDIX B ... 146
APPENDIX C ... 147
APPENDIX D ... 148
APPENDIX E ... 149
APPENDIX F ... 150
APPENDIX G ... 151

Index of Tables & Figures

Table 1: Pea ingredients evaluated in French fry, mozzarella stick, and onion ring applications 14
Table 2: Control batter formula for cook-up starch replacement.. 15
Table 3: Control batter formula for optimized battered French fries with pea ingredients 15
Table 4: Formula for the optimized French fry batter containing pea ingredients 16
Table 5: Chemical composition of starches 22
Table 6: Effect of pea starch on the physiochemical characteristics of battered French fries 23
Table 7: Effect of pea starch on the physiochemical characteristics of temperature abused battered French fries 23
Table 8: Effect of pea starch on the sensory characteristics of battered French fries.................................... 24
Table 9: Effect of pea starch on the sensory characteristics of temperature abused battered French fries 25
Table 10: Effect of pea starch on the instrumental texture of battered French fries..................................... 26
Table 11: Effect of pea starch on the instrumental texture of temperature abused battered French fries 26
Table 12: Effect of pea starch on the instrumental colour of battered French fries 27
Table 13: Effect of pea starch on the instrumental colour of temperature abused battered French fries....... 27
Table 14: Fibre content, particle size and WHC of flours.. 28
Table 15: Fibre content, particle size, and WHC of pea hull fibre.. 29
Table 16: French fry batter formulas: Control and test (pea starch and pea flour) 31
Figure 1: A photograph of fully fried control French fries and French fries containing pea ingredients 31
Table 17: Effect of pea starch and pea flour on the physiochemical characteristics of optimized battered French fries 33
Table 18: Effect of pea starch and pea flour on the physiochemical characteristics of temperature abused optimized battered French fries 34
Table 19: Effect of pea starch and pea flour on sensory characteristics of optimized battered French fries ... 35
Table 20: Effect of pea starch and pea flour on the sensory characteristics of temperature abused optimized battered French fries.. 36
Table 21: Effect of pea starch and pea flour on the instrumental texture of optimized battered French fries. 37
Table 22: Effect of pea starch and pea flour on the instrumental texture of temperature abused optimized battered French fries.. 37
Table 23: Effect of pea starch and pea flour on the instrumental colour of optimized battered French fries . 38
Table 24: Effect of pea starch and pea flour on the instrumental colour of temperature abused optimized battered French fries.. 39
Table 25. Nutritional composition of optimized par fried French fries per 100g[a] 40
Figure 2: Nutritional facts panels for control and test samples of battered, par fried, frozen French fries ... 41
Table 26: Pre-dust and batter ingredient price comparison.. 42
Table 27: Hydrated French fry batter cost estimate (CDN $/lb) 43
Figure 3. Nutrition facts table for Saputo mozzarella sticks... 48
Table 28. Control pre-dust, batter, and breader formulas for coating mozzarella sticks 49
Table 29: Effect of pea starch on the physiochemical characteristics of coated mozzarella sticks.................. 57
Table 30: Effect of pea starch on the physiochemical characteristics of temperature abused coated mozzarella sticks... 58
Figure 4. A photograph comparing fully fried mozzarella sticks from starch replacement phase.................... 58
Table 31 : Effect of pea starch on the sensory characteristics of coated mozzarella sticks 60
Table 32: Effect of pea starch on the sensory characteristics of temperature abused mozzarella sticks 61
Table 33: Effect of pea starch on the instrumental texture of mozzarella stick coatings............................... 62
Table 34: Effect of pea starch on the instrumental texture of temperature abused mozzarella stick coatings 62
Table 35: Effect of pea starch on the instrumental colour of coated mozzarella sticks................................ 63
Table 36: Effect of pea starch on the instrumental colour of temperature abused coated mozzarella sticks . 63
Table 37: Optimized mozzarella stick coating containing pea ingredients and wheat bread crumbs 66
Table 38: Effect of pea ingredients and GF bread crumbs on the mean[1] physiochemical characteristics of coated mozzarella sticks.. 67

Table 39: Effect of pea ingredients and GF bread crumbs on the mean[1] physiochemical characteristics of temperature abused coated mozzarella sticks 68
Table 40: Effect of pea ingredients and GF bread crumbs on the mean[2] sensory evaluation characteristics of coated mozzarella sticks 69
Figure 5. A photograph comparing fully fried mozzarella sticks from pea ingredient optimization phase 69
Table 41: Effect of pea ingredients and GF bread crumbs on the mean[2] sensory evaluation characteristics of temperature abused coated mozzarella sticks 70
Table 42: Effect of pea ingredients and GF bread crumbs on the mean[2] instrumental texture of coated mozzarella sticks 71
Table 43: Effect of pea ingredients and GF bread crumbs on the mean[2] instrumental texture of temperature abused coated mozzarella sticks 71
Table 44: Effect of pea fractions and GF bread crumbs on the instrumental colour of coated mozzarella sticks 72
Table 45: Effect of pea fractions and GF bread crumbs on the instrumental colour of temperature abused coated mozzarella sticks 73
Table 46. Nutritional composition of par fried control and test mozzarella sticks per 100g[A] 74
Figure 6: Nutritional facts panels for control and test samples of breaded, par fried mozzarella sticks 76
Table 47: Coating ingredient price comparison (excluding crumb) 77
Table 48: Coating dry mix cost comparison (CDN /lb) excluding crumb 78
Figure 8: Nutrition facts table for yellow, sliced onions 83
Table 49. Control pre-dust, batter, and breader formulas for onion ring coatings 84
Table 50: Effect of pea starch on the physiochemical characteristics of coated onion rings 92
Table 51: Effect of pea starch on the physiochemical characteristics of temperature abused coated onion rings 92
Table 52: Effect of pea starch on the sensory characteristics of coated onion rings 93
Table 53: Effect of pea starch on the sensory characteristics of temperature abused onion rings 94
Table 54: Effect of pea starch on the instrumental colour of coated onion rings 95
Table 55: Effect of pea starch on the instrumental colour of temperature abused coated onion rings 95
Table 56: Optimized onion ring coating containing pea ingredients and wheat bread crumbs 98
Table 57: Effect of pea ingredients and GF bread crumbs on the mean[1] physiochemical characteristics of coated onion rings 99
Table 58: Effect of pea ingredients and GF bread crumbs on the mean[1] physiochemical characteristics of temperature abused coated onion rings 100
Figure 8. A photograph comparing fully fried onion rings from pea ingredient optimization phase 101
Table 59: Effect of pea ingredients and GF bread crumbs on the mean[2] sensory evaluation characteristics of coated onion rings 101
Table 60: Effect of pea ingredients and GF bread crumbs on the mean[2] sensory evaluation characteristics of temperature abused coated onion rings 102
Table 61: Effect of pea fractions and GF bread crumbs on the mean[2] instrumental colour of fully fried coated onion rings 103
Table 62: Effect of pea fractions and GF bread crumbs on the mean[2] instrumental colour of temperature abused coated onion rings 104
Table 63. Nutritional composition of par fried onion rings per 100g[A] 106
Figure 9: Nutritional fact panels for control and test samples of breaded, par fried onion rings 107
Table 64: Coating ingredient price comparison (excluding crumb) 108
Table 65: Dry pre-dust, hydrated batter, and dry breader cost comparison (CDN $/lb) excluding crumb 109
Figure 10: Pulse Beat article - Pea ingredients in French fries, March 2011 117
Figure 11: CIFST Poster – Pea ingredients in mozzarella sticks, May 2012 118

1.0. INTRODUCTION

Pulses (peas, beans, lentils, and chickpeas) are becoming known in North America as healthy, popular food choices because they are low in fat and high in protein and fibre. Recent research reports conclude that pulses play a role in weight management and may be helpful in the control and prevention of diseases like diabetes and heart disease. Pulses and their ingredients are also gluten-free (GF) with a low glycemic index rating (Patterson, 2003) making them an ideal fit for the rapidly growing "functional" and "gluten-free" food markets. According to a report from Packaged Facts (2011), the global functional food market is expected to exceed $130 billion by year 2015 partially due to rising health and wellness concerns, aging populations, changing lifestyles, and rising disposable income levels in developing countries. Also, the GF market has grown at an average rate of 30% from 2006 to 2010 with approximately $2.6 billion in annual sales in 2010 (Packaged Facts, 2010).

Peas are not only nutritious but they are also environmentally friendly. Peas require half the level of fossil fuel inputs necessary for production compared to other field crops due to their ability to fix nitrogen (Patterson et al 2010). In addition, they contain much higher levels of protein and fibre and are higher in the amino acid, lysine compared to major cereal crops. Lysine is an essential amino acid that one must obtain through the diet because the human body cannot manufacture it. Lysine is important for proper growth as it plays an important role in carnitine production (conversion of fatty acids to energy), calcium absorption, and collagen formation. Thus by supplementing the typical Western wheat based diet with peas, a more nutritious, environmentally friendly, allergen friendly diet can be achieved.

Canada is the largest producer (~25% of total world production) and exporter (40% of total world exports) of field peas in the world (Agriculture and Agri-Food Canada, 2000). Even though Canada is a global leader in yellow field pea (*Pisum sativum*) production, the majority of peas are sold unprocessed to international markets (Pulse Canada, 2007) for seeds, canned goods, soups, ingredients in snack foods, mixes, etc. (Patterson, 2003) or as animal feed. According to Sheri Strydhorst, executive director of the Alberta Pulse Growers Commission, the majority of Canadian peas are exported to two price-sensitive customers; India and China. In Canada, the use of unprocessed peas has been limited in the food sector because they are time consuming to prepare. International market dependence is a major concern and a driving force for diversification through innovative use of peas and pea fractions in food products that would appeal to North American consumers. Consumers in these markets crave and value the health and environmental benefits of pulses in culturally accepted food products such as battered and/or breaded French fries, mozzarella sticks and onion rings.

In Canada, wet and dry pulse milling technologies are used to produce pea fractions such as protein, fibre, and starch. Pea flour can also be dry milled from either yellow or green peas. However, yellow peas tend to be more popular because they are more similar in colour to wheat flour than green peas. Pea flour can be milled from the whole pea or after the pea is split and the hull is removed. Whole pea flour contains a higher level of dietary fibre than split pea flour and as a result, it absorbs more water. It also contains more calcium than split pea flour.

Both pea protein and pea hull fibre have been studied and used in numerous bakery and cereal-based food products to meet consumer demand for higher levels of protein and fibre. Pea protein isolate can be used in food products to increase water or oil absorption and improve texture, cohesion and emulsification (Swanson, 1990). Pea fibre contains both soluble and insoluble fibres and it provides unique nutritional and functional properties to foods (Anderson and Berry, 2003).

Pea starch is regarded as a by-product of protein extraction and is therefore considered a relatively cheap source of starch compared to corn, wheat, and potato starches (USA Dry Pea and Lentil Council, 2010). It has excellent gelling, fat limiting and water binding properties (Ratnayake, 2000). Pea starch is most commonly used in industrial paper applications yet overall demand is low. In Canada, it is commercially available as a native starch (rather than modified). Pea starch is primarily underutilized because of limited knowledge of its functionality in alternative applications including food systems.

Previous research conducted at the FDC reported that pea starch, pea flour, and pea hull fibre incorporated in the coatings of chicken and fish nuggets increased crispness, hold-time, and golden colour of the final products. The use of pea ingredients in coated chicken and fish nuggets also resulted in finished products having an "excellent source of fibre claim" and cleaner labels as it was possible to remove gum(s) and caramel colour.

The objective of this project was to evaluate the suitability of pea starch and other pea ingredients as replacements for traditional ingredients such as corn starch, wheat, soy, and corn flours, wheat gluten, gums, whey, and colour in coatings for French fry, onion ring and mozzarella stick applications. Physiochemical, sensory, nutritional, and economic aspects of utilizing pea ingredients were assessed. The research was carried out in collaboration with Newly Weds Foods and Canada's three major pea processors to ensure industry relevance of the research findings.

This report presents the research findings for native pea starch replacement of modified corn starch in battered French fries, breaded mozzarella sticks and onion rings, as well as, the use of pea starch, flour, hull fibre, and protein combinations to develop optimized coatings for the three applications. The report is divided into three chapters corresponding to the product applications and it reports noteworthy conclusions and recommendations regarding the use of pea ingredients in batter and breading applications. A literature review highlighting pea production, pea milling, ingredient functionality, coating technology, and French fry, mozzarella stick, and onion ring processing and evaluation methods is also included (Appendix A).

Funding for this project was provided by Alberta Crop Industry Development Fund Ltd., Alberta Pulse Growers Commission, Pulse Canada, Manitoba Pulse Growers Association, and Parrheim Foods. In kind support was provided by Newly Weds Foods, Nutri-Pea Ltd., Best Cooking Pulses, and Parrheim Foods.

2.0. FRENCH FRIES

2.1. Experimental design

The research was organized into two phases: (1) cook-up starch replacement and (2) optimized coatings with pea ingredients. Two native pea starches manufactured in Canada were evaluated independently as replacements (100%) for modified cook-up corn starch in batters for French fries. French fry batters commonly include both cook-up and instant starch to reduce fat uptake and increase crispness of fully fried French fries. Both cook-up corn starch and native pea starch gelatinize when heat is applied, whereas, instant corn starch is typically pre-gelatinized or gels at a low temperature. Thus to provide a good comparison between the functionality of corn and pea starches in a single pass batter application, only modified cook-up corn starch was replaced with pea starch in the first phase. In the second phase, the most successful pea starch was used in combination with additional pea ingredients in the development of optimized French fry coatings containing pea ingredients. Pea starch was evaluated as a replacement for both cook-up and instant corn starches (100%). Three pea flours, three pea hull fibres, and one pea protein isolate were evaluated as replacements for wheat flour, corn flour, gum, and colouring. Table 1 shows the pea fractions examined, the supplier, and the method of fractionation.

Table 1: Pea ingredients evaluated in French fry, mozzarella stick, and onion ring applications

Research Phase	Product	Supplier	Fractionation Method
Pea Starch Replacement	Accu-Gel™	Nutri-Pea Limited	Wet
	Starlite™	Parrheim Foods	Dry
Optimized Pea Prototype Development	Best™ Whole Pea Flour	Best Cooking Pulses	Dry
	Best™ Split Pea Flour	Best Cooking Pulses	Dry
	Fiesta™ Split Pea Flour	Parrheim Foods	Dry
	Best™ Pea Hull Fibre	Best Cooking Pulses	Dry
	Exlite™ Pea Hull Fibre	Parrheim Foods	Dry
	Centara™ III Pea Hull Fibre	Nutri-Pea Limited	Wet
	Propulse™ Pea Protein Isolate	Nutri-Pea Limited	Wet

2.2. Materials

2.2.1. Potatoes

Russet Burbank potatoes, a cultivar commonly used for French fry production, were supplied by Kehler Farms Ltd. of Carman, MB. Potatoes (150 kg in total) were one to three months post-harvest and stored in a commercial potato bin (Kehler Farms Ltd.) with controlled temperature and relative humidity. Prior to processing at FDC, potatoes were stored at 10-15^{o}C for up to one week. Specific gravity of the potatoes was assessed prior to processing to ensure a consistent raw material. Acceptable specific gravity was greater than 1.080 with a target of 1.095 (USDA Grades for Potato Processing).

$$\text{Specific Gravity} = \frac{\text{potato weight in air (g)}}{\text{potato weight in air (g)} - \text{potato weight in water (g)}}$$

2.2.2. Coating system

Commercial French fry batter dry mixes were supplied by Newly Weds Foods (Mississauga, ON). Tables 2 and 3 show the “Base” supplied by Newly Weds Foods and the control batter formulation for each phase: (1) cook-up starch replacement and (2) optimized French fry coating with pea ingredients.

Table 2: Control batter formula for cook-up starch replacement

Ingredient Type		Starch Replacement Formula	Complete Dry Mix Formula	Hydrated Batter
		%		
Base	Salt - fine flake	9.02	67.00	27.92
	Oleo paprika	0.02		
	Oleo turmeric	0.01		
	Oil - vegetable	0.10		
	Phosphate - SAPP*	0.34		
	Sodium bicarbonate	0.25		
	Onion powder	1.00		
	Garlic powder	1.20		
	Yeast	0.25		
	Wheat flour - soft unbleached	41.24		
	Wheat flour - all purpose unbleached	23.01		
	Corn flour - yellow	23.01		
	Gum - xanthan	0.30		
	Colour - Maillose®	0.25		
Starch - cook-up, corn, modified		----	13.00	5.42
Starch - instant, corn, modified		----	20.00	8.33
	Dry Mix Formula	**100.00**	**100.00**	
Water (13°C)				58.33
			Hydrated Batter (1.4 parts water : 1.0 part dry mix)	**100.00**

* Sodium acid pyrophosphate

Table 3: Control batter formula for optimized battered French fries with pea ingredients

Ingredient Type		Seasoning Blend Formula	Complete Dry Mix Formula	Hydrated Batter
		%		
Base	Salt - fine flake	74.61	8.10	3.37
	Oleo paprika	0.17		
	Oleo turmeric	0.06		
	Phosphate - SAPP*	2.83		
	Sodium bicarbonate	2.07		
	Onion powder	8.28		
	Garlic powder	9.93		
	Yeast	2.05		
Wheat Flour - soft unbleached		----	27.62	11.51
Wheat Flour - all purpose unbleached		----	15.42	6.42
Corn Flour - yellow		----	15.42	6.42
Gum - xanthan		----	0.20	0.08
Colour - Maillose®		----	0.17	0.07
Oil - vegetable, non hydrogenated		----	0.07	0.03
Starch - cook-up, corn, modified		----	13.00	5.42
Starch - instant, corn, modified		----	20.00	8.33
	Dry Mix Formula	**100.00**	**100.00**	
Water (13°C)				58.33
			Hydrated Batter (1.4 parts water : 1.0 part dry mix)	**100.00**

* Sodium acid pyrophosphate

Table 4 shows the optimized French fry batter formulation where pea starch replaced both cook-up and instant starches and pea flour replaced the three traditional flours, xanthan gum, and caramel colour. The "Base" was blended with additional ingredients at FDC using a Hobart food mixer with a wire whisk attachment. Viscosity was measured with a Stein Cup (seconds of flow from full to empty) to represent the industry method, as well as with a Brookfield Viscometer (Model RVDV-II +PRO) with spindle 3 at 100 RPM for 15 seconds for better accuracy.

Table 4: Formula for the optimized French fry batter containing pea ingredients

Ingredient Type		**Seasoning Blend Formula**	**Complete Dry Mix Formula**	**Hydrated Batter**
		%		
Base	Salt - fine flake	74.61	8.10	3.37
	Oleo paprika	0.17		
	Oleo turmeric	0.06		
	Phosphate - SAPP**	2.83		
	Sodium bicarbonate	2.07		
	Onion powder	8.28		
	Garlic powder	9.93		
	Yeast	2.05		
Pea Flour - whole or split*		----	58.83	24.52
Oil - vegetable, non hydrogenated		----	0.07	0.03
Pea Starch - cook-up, native		----	33.00	13.75
	Dry Mix Formula	**100.00**	**100.00**	
Water (13°C)				58.33
			Hydrated Batter (1.4 parts water : 1.0 part dry mix)	**100.00**

* Split pea batter was hydrated 1.4 parts water: 1.0 part dry mix and whole pea batter was hydrated 1.65 parts water: 1.0 part dry mix

** Sodium acid pyrophosphate

2.3. Sample preparation

Potatoes were washed, towel dried, peeled (hand peeler), and pre-heated in a water bath (58°C / 136°F) for 25 minutes to an internal temperature of (49-54°C / 120-129°F). Potatoes were then manually cut into 3/8" x 3/8" straight cut fries using a tabletop French fry cutter with stationary blades. Fries were manually graded to remove pieces that were shorter than 3 inches, longer than 4.75 inches, and with ends thinner than 0.3 inches. Fries were blanched in a water bath (68-74°C / 155-165°F) for 15 minutes then dipped into a solution (20-25°C / 68-77°F) of 0.7% sodium acid pyrophosphate (SAPP) for 45 seconds to reduce browning. Batter was prepared while potatoes were blanching then held over ice to maintain temperature (<15^{o}C / 59^{o}F). French fries were dried for two minutes at 93^{o}C (200^{o}F) on perforated sheet pans in a rotating convection oven (Hobart Rotating Oven H0300G, Model ML-132178). Fries were manually dipped into batter using a fork for five seconds and allowed to drip one minute on a wire rack. Then, fries were par fried (Garland Deep Fryer, SF) at 190^{o}C (375^{o}F) for 45 seconds using non-hydrogenated canola oil (Canola Harvest). Batter pick-up was taken in duplicate using two fries as a sample and batch weights were taken to calculate total batch pick-up.

$$\text{Batter Pick-up (\%)} = \frac{\text{(battered batch wt - dried wt)}}{\text{battered batch wt}} \times 100$$

Fryer capacity was 18L. To maintain oil quality, 6L of used oil was blended with 12L of fresh oil after every eight batches. After each batch, crumbs from the fryer and fryer basket were collected and weighed. Oil was filtered between batches through a number 40 (425 micron) WS Tyler Canadian Standard Sieve (St. Catharines, ON). Any crumbs left in the sieve were weighed and the crumb residue was calculated.

$$\text{Crumb Residue (\%)} = \frac{\text{crumb wt}}{\text{frozen batch wt}} \times 100$$

Par fried French fries were placed on a wire rack to drain, then transferred to parchment lined sheet pans and frozen overnight at -18^{o}C (0^{o}F). French fries were then bagged and returned to the freezer (-18^{o}C). Batch weights were recorded at each stage. Four batches were made of each treatment to eliminate processing effects and to generate a larger number of 'batch' observations.

$$\text{Par Fry Yield (\%)} = \frac{\text{par fry batch wt}}{\text{battered batch wt}} \times 100$$

Par fried French fries were stored frozen for a minimum of 14 days. An equal portion from each of the four batches were blended together to create a pooled sample for each treatment. Samples were fully fried for sensory and objective testing in a deep fryer (Garland Deep Fryer, SF) at 177^{o}C (350^{o}F) for 2 minutes and 30 seconds (per Newly Weds Foods) using non-hydrogenated canola oil (Canola Harvest). Cooked weights were taken and cook yield was calculated based on frozen batch weight.

$$\text{Cook Yield (\%)} = \frac{\text{cooked batch wt}}{\text{frozen batch wt}} \times 100$$

2.4. Test methods

2.4.1. Sensory evaluation

Sensory evaluation by a trained panel was used to quantify the intensities of eight attributes. A 13-person trained panel, with sensory evaluation experience, was intensively trained in three 2 hour sessions. Category scales (4 or 8 points) were used for the following attributes: surface texture, exterior bite, crispness, overall moistness, baked potato flavour, off flavour and overall quality (Appendix B). Colour was subjectively assessed using the United States Department of Agriculture Colour Standards for Frozen French Fried Potatoes (modified scale) (Appendix C). French fries were placed under a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs and were evaluated 5 and 30 minutes after frying. Current food service practices dictated the hold time chosen for this study. Products were presented to the panellists in random order and labelled with random three-digit codes. French fry size and variability were minimized by serving three random fries per sample from a pooled sample of the four production dates. Panellists were given room temperature distilled water and unsalted crackers to cleanse their palate between samples. Panellists evaluated two to three samples per panel session to minimize sensory fatigue.

2.4.2. Nutritional analysis

Nutritional analysis of frozen par fried French fries was conducted by SGS Canada Inc. (Vancouver, BC) for the following: energy, protein, fat, calories from fat, saturated fat, monounsaturated fat, polyunsaturated fat, trans fat, cholesterol, carbohydrates, total sugar, total dietary fibre, insoluble fibre, soluble fibre, sodium, calcium, iron, moisture, ash, vitamin A and vitamin C. All methods used were AOAC International approved and in compliance with Health Canada regulations for nutritional analysis of food products.

2.4.3. Weight loss

Weight loss over time was determined by testing four randomly selected fully fried French fries from each treatment after 30 minutes of exposure to the food warmer (OHC-500 Heat Lamp). Whatman 1 filter papers (1.5mm thick) were weighed. A sample (one fry) was placed on each filter paper and sample weight was recorded at time 0. Filter papers with samples were placed (minimum of 12mm spacing) beneath the food warmer (heat lamps at maximum height of 35cm above sample) and held for 30 minutes. After 30 minutes, samples were removed and the filter paper was weighed. Data was reported as the percentage of weight lost over time per gram of sample.

$$\text{Weight loss (\%)} = \frac{\text{Paper wt @ 30 min} - \text{Paper wt @ 0 min}}{\text{Sample wt @ 0 min}} \times 100$$

2.4.4. Instrumental texture

Texture analysis was performed in triplicate using a modified method (Texture Technologies Corp, 29W) to assess French fry crispness/crunchiness and overall firmness over time. This cut test was designed to imitate incisor teeth cutting through French fries and to measure crispness based on the initial slope and overall firmness based on total energy required to cut through the fries. This method was designed to identify tougher French fries as perceived by sensory assessment. All tests were conducted using a TA-XT2i Texture Analyzer with a 25kg load cell equipped with a TA-42 Knife with a 45° Chisel blade and guillotine plate. Three fries were lined up across the guillotine holder so that the knife would contact the midpoint of the fries perpendicularly and fully cut through. The sequence was a Return-to-Start test with a button trigger, a test distance of 15mm, a pre-test crosshead speed of 3mm/sec until 5g of resistance was sensed then a decrease to a test crosshead speed of 2.5mm/sec, and a return speed of 10mm/sec. Fries were tested three minutes after frying and again after holding 30 minutes in the food warmer. The initial slope (g/sec) is the primary force-based crispness. The total energy (area under the curve; g/sec) is a measure of the overall French fry firmness. Appendix D shows a typical curve that is generated by the texture analyzer and highlights where the values to measure the firmness and crispness/crunchiness are taken from.

2.4.5. Instrumental colour

Coating colour measurements were taken on four randomly selected fully fried samples from each treatment after 5 and 30 minutes of exposure to the food warmer. Three measurements from random locations on the fry surface were taken per sample; two from one side and one from the opposite side. The Konica Minolta chroma meter (Model CR-400) was used to determine CIE L*a*b* values using an 8 mm aperture. L* is an approximate measurement of brightness and ranges from 0 (black) to 100 (white); a* reports positive values for redness and negative values for greenness; b* reports positive values for yellowness and negative values for blueness (Francis and Clydesdale, 1975). The chroma meter was calibrated with a white tile prior to testing (No. 18733148: CIE L* 97.63, a* -0.01, b* 1.60).

2.4.6. Freeze-thaw stability

Par fried French fries were temperature abused through two freeze-thaw cycles. Samples were removed from the storage freezer (-18^{o}C) and placed on parchment lined sheet pans, covered with plastic wrap and held at room temperature (one to two hours). Samples were tempered to a surface temperature of 4^{o}C then blast frozen

(Victory CO_2 Blast Freezer) for 20 minutes at -40^oC to a surface temperature of -25^oC. Samples were stored overnight in a walk-in storage freezer at -18^oC. The tempering and blast freezing process was repeated; then samples were repackaged and stored in the freezer at -18^oC for a minimum of 14 days. Freeze-thaw samples were evaluated by a 5-person trained sensory panel rather than a 13-person trained sensory panel due to limited product.

2.5. Statistical analysis

Statistical analysis of variance (ANOVA) was carried out using Predictive Analytics SoftWare 12.0.1 for windows (PSAW, formerly known as SPSS) (IBM Corporation, Somers, NY). Treatment means were separated (α = 0.05 level of significance) with Tukey or Scheffe, depending on equality of sample size.

2.6. Results & discussion

2.6.1. Starch replacement

A. Physiochemical characteristics

The performance of pea starch as a replacement for cook-up corn starch in a commercial French fry batter was evaluated at 100% replacement level. There are two methods (wet and dry) of separating starch from other fractions. The milling process affects starch purity and properties. Dry milling is generally known to produce a less pure starch with more starch damage; however, it is a more economical process. Table 5 compares the chemical composition of the control and test starches. French fry batters containing wet milled native pea starch, Accu-Gel™, or dry fractionated native pea starch, Starlite™, performed similarly to the control batter containing chemically modified, wet milled corn starch.

Table 5: Chemical composition of starches

	Starch*	Protein*	Fat*	Amylose*
		%		
Modified corn starch (control)	79.9	0.4	0.7	28.2
Accu-Gel™ (wet milled)	77.8	0.4	0.1	32.2
Starlite™ (dry milled)	65.6	8.0	0.9	33.2

* Based on chemical analysis, reported on as-is basis; SGS Canada

Physiochemical data (Table 6) showed that pea starch significantly thickened batter compared to the cook-up corn starch control (Batterbind™ S, National Starch). Vose (1977) observed that starch damage that occurs during fractionation can subsequently cause higher viscosity when the damaged starch is solubilized. Pea starch possesses larger granules than corn starch so pea starch granules are more damaged during milling than corn starch granules (Vose, 1977). Pea starch's larger granules also absorb more water than corn starch granules. Thus, viscosity of both pea starch batters was significantly higher than batter made with corn starch. In addition, dry milled pea starch (Starlite™) created a significantly more viscous batter than wet milled pea starch (Accu-Gel™) most likely because more starch damage and protein present from dry milling. Olewnik and Kulp (1990) reported that hard wheat flours with high protein and starch damage levels resulted in thicker batters; which supports the findings in this study.

Both pea starch batters had significantly higher batter pick-ups than the control which can be attributed to their higher batter viscosity. Though statistically significant, batter pick-up from 15-17% is acceptable for commercial processing of French fries, thus, the replacement of cook-up corn starch with pea starch did not affect the processing capability of the batter.

A primary concern when using native starch instead of modified starch is inferior moisture retention and/or oil wicking in a food system. Weight loss of French fries made with dry milled, Starlite™ pea starch was similar to that of the control after holding under a heat lamp for 30 minutes while wet milled, Accu-Gel™ French fries lost significantly more weight than the control (Table 6). The higher level of protein in dry milled Starlite™ may have enhanced its weight retention. No difference in total moisture content was observed between the three par fried French fry prototypes. No significant differences were observed between battered French fries containing pea or corn starch for par fry yield, cook yield, or crumb production in the fryer (Table 6).

Table 6: Effect of pea starch on the physiochemical characteristics of battered French fries

	Control[1]	Accu-Gel™[1]	Starlite™[1]	P-value
	Corn Starch	Pea Starch	Pea Starch	
Batter Viscosity[2], centipoises	434[a]	622[b]	706[c]	0.000
Batter Pick-up, %	15.13[a]	16.57[b]	17.68[b]	0.006
Par fry Yield, %	84.61	84.45	85.46	0.410
Crumb Production, %	2.40	2.12	2.54	0.577
Cook Yield, %	72.45	70.71	72.25	0.859
Weight Loss, %	1.30[a]	2.56[b]	1.89[ab]	0.039
Total Moisture[3], %	65.80	66.40	65.50	--

[1] Means represent quadruplicate observations
[2] Measured with a Brookfield viscometer (Model RVDV-11 +PRO) with spindle 3 at 100RPM
[3] SGS Canada Inc. method 03-01-SLM-FD-0009 on par fried French fries
[a,b,c] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Table 7 shows that after temperature abuse, French fries coated with batters containing pea starch maintained a cook yield, weight loss, and moisture level similar to the control.

Table 7: Effect of pea starch on the physiochemical characteristics of temperature abused battered French fries

	Control[1]	Accu-Gel™[1]	Starlite™[1]	P-value
	Corn Starch	Pea Starch	Pea Starch	$P \leq .05$
Cook Yield, %	78.95	78.78	75.96	0.071
Weight Loss, %	2.47	2.91	2.83	0.497
Total Moisture[2], %	66.30	66.40	68.00	--

[1] Means represent quadruplicate observations
[2] SGS Canada Inc. method 03-01-SLM-FD-0009 on par fried French fries

B. Sensory evaluation

Table 8 shows that battered French fries with pea starch (Accu-Gel™ or Starlite**™**) in the coating were similar to control fries with corn starch in the coating for overall quality (slightly to moderately high), exterior bite (slightly to moderately tender), baked potato flavour (slight), and off-flavour (none). Sensory panellist ratings indicate that French fries made with Accu-Gel**™** pea starch were more similar to control French fries than fries using Starlite™ pea starch. French fries with Accu-Gel™ pea starch were perceived to be more moist (moderately moist versus slightly dry) after a 30 minute hold time compared to the control and Starlite™ French fries ($p \leq 0.05$) although no difference in moisture content was observed among the three prototypes.

Olewnik and Kulp (1990) found that as level of protein in fried chicken batters was increased, fried coatings were crisper, had a rougher surface texture, and a darker colour. French fries prepared with Starlite™ pea starch were more crispy, had a more golden colour, and a slightly rougher surface texture at 5 and 30 minutes ($p \leq 0.05$) than control and Accu-Gel™ French fries (Table 8). More golden/darker colour was also observed in Starlite™ French fries compared to Accu-Gel™ and control French fries. Thus based on Olewnik and Kulp's battered chicken research, the increased crispness, rougher surface texture, and darker colour found in Starlite™ French fries compared to Accu-Gel™ and control French fries was likely due to Starlite™'s higher protein content. The darker colour observed by panellists was likely due to the additional protein from the pea starch that was available to participate in the Maillard browning reaction.

Table 8: Effect of pea starch on the sensory characteristics of battered French fries

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	Pea Starch	Pea Starch	
Colour	5	0.50[a]	0.15[a]	1.10[b]	0.000
0=white; 6=brown	30	0.10[a]	0.10[a]	1.25[b]	0.000
Surface Texture	5	2.90[b]	3.20[b]	2.10[a]	0.005
1=rough; 4=smooth	30	3.10[b]	3.10[b]	2.30[a]	0.008
Exterior Bite	5	3.50	3.40	3.90	0.380
1=tender; 8=tough	30	4.30	4.78	5.10	0.312
Crispness	5	5.20[a]	4.60[a]	6.30[b]	0.000
1=soggy; 8=crispy	30	4.40[a]	4.50[a]	5.50[b]	0.005
Moistness	5	4.80	5.70	5.20	0.328
1=dry; 8=moist	30	4.40[a]	6.20[b]	4.90[a]	0.009
Off Flavour	5	1.00	1.00	1.00	0.999
1=none; 4=extreme	30	1.00	1.00	1.00	0.999
Potato Flavour	5	2.30	2.60	2.40	0.793
1=none; 4=extreme	30	2.10	2.30	2.10	0.836
Overall Quality	5	5.60	5.40	6.00	0.297
1=low; 8=high	30	4.80	4.70	4.80	0.973

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 13-person trained sensory panel
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

French fries were subjected to temperature abuse then re-evaluated by a 5-person trained sensory panel. Sensory characteristics of French fries containing pea starch were not significantly affected by temperature abuse when compared to the control (Table 9). After temperature abuse, overall quality of all French fry prototypes was considered slightly high.

Table 9: Effect of pea starch on the sensory characteristics of temperature abused battered French fries

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	**Pea Starch**	**Pea Starch**	
Colour	5	0.04	0.08	0.08	0.614
0=white; 6=brown	30	0.23	0.08	0.04	0.117
Surface Texture	5	2.92	2.77	2.38	0.125
1=rough; 4=smooth	30	2.77	2.54	3.08	0.232
Exterior Bite	5	3.15	2.92	3.62	0.362
1=tender; 8=tough	30	5.00	4.38	4.85	0.284
Crispness	5	5.77	5.31	5.46	0.498
1=soggy; 8=crispy	30	5.00	4.85	4.23	0.089
Moistness	5	5.85[b]	5.46[ab]	4.15[a]	0.013
1=dry; 8=moist	30	5.00	5.31	4.38	0.260
Off Flavour	5	1.08	1.00	1.00	0.387
1=none; 4=extreme	30	1.00	1.00	1.00	0.999
Potato Flavour	5	2.38	2.23	2.54	0.682
1=none; 4=extreme	30	2.23	2.38	2.31	0.912
Overall Quality	5	5.77	5.54	5.23	0.297
1=low; 8=high	30	4.69	4.85	4.69	0.973

[1] Holding in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 5-person trained sensory panel
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

C. Objective results

Instrumental texture analysis generally resulted in a greater initial slope after 30 minutes in the food warmer meaning French fries became crispier over time. However, the sensory panellist ratings indicated that French fries became less crispy and tougher over time; although, no significant difference was found. Thus, it appears that the initial slope more accurately measured crunchiness (hard coating) than crispness (flaky coating) based on sensory findings. Table 10 shows that both pea starches increased ($p \leq 0.05$) French fry crispness/crunchiness after 3 minutes in a food warmer compared to control fries while sensory data found Starlite™ French fries were crispier ($p \leq 0.05$) at 5 and 30 minutes compared to Accu-Gel™ and control fries. As expected, overall firmness (toughness) scores for all French fry samples increased after 30 minutes in a food warmer.

Table 10: Effect of pea starch on the instrumental texture of battered French fries

	Time[1]	Control[2] Corn Starch	Accu-Gel™[2] Pea Starch	Starlite™[2] Pea Starch	P-value
Crunchiness[3]	**3 min**	618.93[a]	1075.51[b]	1052.57[b]	0.036
Overall Firmness[4]		8575.38	7926.88	8378.52	0.708
Crunchiness[3]	**30 min**	915.67[ab]	705.77[a]	1152.77[b]	0.013
Overall Firmness[4]		9423.01	8693.72	8832.00	0.497

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent triplicate observations
[3] Crunchiness determined by the initial gradient (slope); g/sec. Higher number = crunchier.
[4] Overall firmness determined by the area under the texture analysis curve, g*sec. Higher number = firmer.
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

At 3 minutes, French fries made using Starlite™ were less crunchy and less firm ($p \leq 0.05$) than control fries but after the 30 minute hold period, no significant differences were seen (Table 11). Similarly, the trained panel did not pick up any significant textural differences between temperature abused samples after 30 minutes of holding.

Table 11: Effect of pea starch on the instrumental texture of temperature abused battered French fries

	Time[1]	Control[2] Corn Starch	Accu-Gel™[2] Pea Starch	Starlite™[2] Pea Starch	P-value
Crunchiness[3]	**3 min**	972.17[b]	884.51[b]	683.73[a]	0.023
Overall Firmness[4]		8152.76[b]	7764.11[ab]	6293.53[a]	0.002
Crunchiness[3]	**30 min**	1044.27	942.34	1024.78	0.566
Overall Firmness[4]		8191.71	8560.61	9084.67	0.664

[1] Holding (minutes) in a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent triplicate observations
[3] Crunchiness determined by the initial gradient (slope); g/sec. Higher number = crunchier.
[4] Overall firmness determined by the area under the texture analysis curve, g*sec. Higher number = firmer.
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Pea starch in the batter did not significantly affect colour of the fully fried French fries except for brightness (L*) after 30 minutes of hold time (Table 12). Starlite™ containing French fries were significantly less bright than control fries after 30 minutes in the food warmer. Sensory panellists also noted a darker colour in Starlite™ containing French fries compared to the control. No significant differences in the colour of temperature abused French fries were observed with the exception of Accu-Gel™ fries being significantly less bright after 30 minutes hold time than control and Starlite™ fries (Table 13).

Table 12: Effect of pea starch on the instrumental colour of battered French fries

	Time[1]	Control[2] Corn Starch	Accu-Gel™[2] Pea Starch	Starlite™[2] Pea Starch	P-value
L* (0=black; 100=white)	**5 min**	56.71	56.62	55.88	0.531
a* (Pos=red; Neg=green)		0.43	0.17	0.56	0.769
b* (Pos=yellow; Neg=blue)		16.93	16.91	16.46	0.918
L* (0=black; 100=white)	**30 min**	63.31[b]	62.58[ab]	60.59[a]	0.044
a* (Pos=red; Neg=green)		- 0.89	0.17	0.02	0.082
b* (Pos=yellow; Neg=blue)		18.29	18.50	18.07	0.902

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent 12 observations
[a, b] Means with differing superscripts are significantly different (p≤.05) across rows

Table 13: Effect of pea starch on the instrumental colour of temperature abused battered French fries

	Time[1]	Control[2] Corn Starch	Accu-Gel™[2] Pea Starch	Starlite™[2] Pea Starch	P-value
L* (0=black; 100=white)	**5 min**	59.65	58.90	58.37	0.561
a* (Pos=red; Neg=green)		- 0.79	- 0.12	0.24	0.321
b* (Pos=yellow; Neg=blue)		15.09	14.06	16.27	0.271
L* (0=black; 100=white)	**30 min**	60.46[b]	57.47[a]	60.94[b]	0.011
a* (Pos=red; Neg=green)		- 0.84	- 0.28	- 0.26	0.497
b* (Pos=yellow; Neg=blue)		17.33	16.04	17.24	0.413

[1] Holding (minutes) in a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent 12 observations
[a, b] Means with differing superscripts are significantly different (p≤.05) across rows

Both native pea starches (Accu-Gel™ and Starlite™) were acceptable replacements for modified corn starch in battered French fries. The functional and sensory properties of Accu-Gel™ batters and coated French fries were generally more similar to the control, thus, it was chosen for use in phase 2 of the French fry research.

2.6.2. Development of optimized French fry coating with pea ingredients

Accu-Gel™ pea starch was used in combination with pea flour, protein, and fibre to make GF battered French fries. Accu-Gel™ replaced both cook-up and instant corn starches. Three pea flours were evaluated in the French fry batter; Best™ whole and split pea flours and Fiesta™ split pea flour. The water holding capacity (WHC), fibre content, and particle size distribution of pea flours were examined to better understand their function in the batter application (Table 14).

Table 14: Fibre content, particle size and WHC of flours

Flour Type	Total Dietary Fibre[1]	Soluble Fibre[1]	Insoluble Fibre[1]	Particle Size[2]	WHC[3]
	%	%	%	microns	%
All Purpose Wheat	2.5	1.0	1.6	--	--
Corn Flour	2.7	0.5	2.2	--	--
Best™ Whole Pea	13.0	1.5	12.0	700	190
Best™ Split Pea	11.0	1.5	9.7	700	150
Fiesta™ Split Pea	11.0	4.7	6.4	425	101

[1] Based on chemical analysis, reported on as-is basis; SGS Canada
[2] Based on ingredient specification
[3] Water holding capacity; modified AACC Method 88.04

Best™ whole pea flour had the highest level of insoluble fibre (12%) which resulted in the highest WHC (190%) and produced the thickest (highest viscosity) batter compared to control and other test flours. The whole pea flour batter was gritty and too thick for processing (150 seconds Stein Cup versus control with an 18 seconds Stein Cup). Consequently, hydration for the whole pea flour batter was increased from 1.4 to 1.65 parts water for each part dry batter mix to obtain a Stein Cup value of 25 seconds; thus, making the whole pea flour batter process capable.

Split pea flours (Best™ and Fiesta™) had a WHC of 150% and 101%, respectively. Fiesta™ was preferred as it produced a smoother, thinner batter (37 seconds Stein Cup) compared to the gritty, thicker (50 seconds Stein cup) batter produced by Best™ split pea flour. Best™ split pea flour batter had to be thinned to properly batter potato strips. Batter viscosity and texture differences were attributed to Best™ split pea flour's larger particle size (700 micron (BCP split) vs 425 micron (Fiesta™)) and higher levels of insoluble fibre (9.7% (Best™ split) vs 6.4% (Fiesta™)) even though total dietary fibre of the two split pea fibres was the same (11%).

When using pea flour in French fry batter, it is recommended to choose flour that is equal to or less than 425 microns in size with a WHC equal to or less than 100% to reduce excess batter viscosity. If using flour with a higher WHC, batter hydration may need to be increased to maintain a process capable batter viscosity (15-40 seconds Stein Cup / 400-600 centipoise).

Two dry fractioned pea hull fibres (Best™ and Exlite™) and one wet fractioned pea hull fibre (Centara™) were tested in French fry batters but they were not considered beneficial because the amount of fibre required for a fibre content claim resulted in excessive batter thickness. The WHC of each pea fibre was determined using modified AACC Method 88.04 (Table 15). Pea fibre samples ranged from 355-420% WHC and particle size ranged from 106-125 microns based on ingredient specifications.

Table 15: Fibre content, particle size, and WHC of pea hull fibre

Fibre	**Total Dietary Fibre[1]**	**Soluble Fibre[1]**	**Insoluble Fibre[1]**	**Particle Size[2]**	**WHC[3]**
	%	%	%	Microns	%
Best™ (dry)	82	5.9	76.5	125	376
Exlite™ (dry)	74	6.8	67.3	106	355
Centara™ (wet)	86	5.4	80.6	106	420

[1] Based on chemical analysis, reported on as-is basis; SGS Canada
[2]Based on ingredient specification
[3] Water holding capacity; modified AACC Method 88.04

Pea fibre with higher insoluble fibre content and higher WHC resulted in thicker batters. Exlite™ had the lowest WHC (355%) and resulted in the thinnest batter, while Centara™ had the highest WHC (420%) and highest batter viscosity. When using pea fibre in French fry batter, it is recommended to choose an ingredient with a WHC of 350% or less in order to reduce batter bulking. The small difference in particle size between pea fibres did not affect their performance in the French fry batter.

Preliminary testing of pea protein isolate (Propulse™) as a replacement for 25% of the cook-up starch in French fry batter resulted in a slightly thicker batter and a tougher coating on the finished fry which was less preferred than the control by sensory panellists. Thus, no further testing of pea protein was conducted.

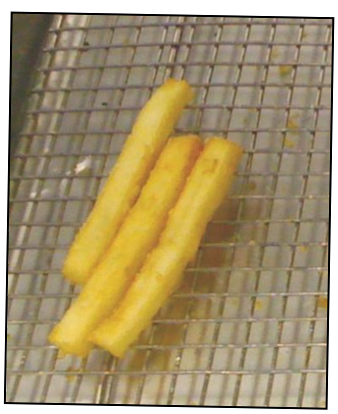
The most promising French fry prototypes were those with batters containing pea starch and pea flour. Xanthan gum (for viscosity control) and Maillose® caramel colour were removed from the test batters because the pea flour provided sufficient thickening and colour. Four optimized French fry prototypes with different combinations of pea starch and pea flour were developed. The prototypes tested were: (A) 100% replacement of cook-up corn starch only with Accu-Gel™ pea starch plus 100% replacement of wheat and corn flours with Fiesta™ split pea flour, (B) 100% replacement of both cook-up and instant corn starch with Accu-Gel™ pea starch plus 100% replacement of wheat and corn flours with Fiesta™ split pea flour, (C) and (D) prototypes were the same as prototypes (A) and (B) except Best™ whole pea flour was tested in place of Fiesta™ split pea flour. Best™ split pea flour was not included due to the gritty texture imparted to the batter. Table 16 shows the control and test batter formulations used to make prototypes of battered French fries for assessment of physiochemical, sensory, and nutritional properties and cost estimates. Figure 1 is a photograph of the control French fry and prototype D (full replacement of both corn starches with Accu-Gel™ pea starch and full replacement of wheat and corn flour with Best™ whole pea flour).

Table 16: French fry batter formulas: Control and test (pea starch and pea flour)

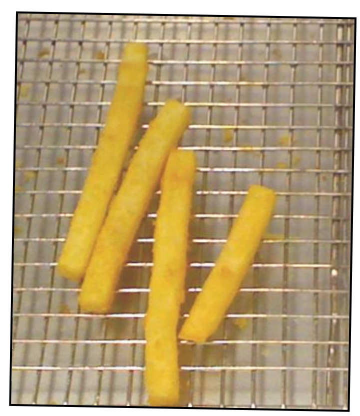
	Control[1]	A[2]	B[3]	C[4]	D[5]
Cook-up Starch	**Corn**	**Pea**	**Pea**	**Pea**	**Pea**
Instant Starch	**Corn**	**Corn**	**Pea**	**Corn**	**Pea**
Flour	**Wheat**	**Split Pea**	**Split Pea**	**Whole Pea**	**Whole Pea**
Water	58.33	58.33	58.33	62.47	62.47
Wheat Flour	16.93	---	---	---	---
Corn Flour	6.42	---	---	---	---
Pea Flour	---	24.52	24.52	22.08	22.08
Corn Starch, Cook-up	5.42	---	---	---	---
Corn Starch, Instant	8.33	8.33	---	7.50	---
Pea Starch, Cook-up	---	5.42	13.75	4.88	12.38
Oil, Vegetable	0.03	0.03	0.03	0.03	0.03
Seasoning Base	3.37	3.37	3.37	3.04	3.04
Xanthan Gum	0.08	---	---	---	---
Maillose® Colour	0.07	---	---	---	---
Total	100.00	100.00	100.00	100.00	100.00

[1] Control made with all purpose and soft wheat flour and modified corn starches; 1.4 parts water: 1 part dry
[2] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.65 parts water: 1 part dry
[5] Made with Best™ whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry

Figure 1: A photograph of fully fried control French fries and French fries containing pea ingredients



Control French fries
(Corn starch, corn flour, wheat flour, gum, colour)



Typical optimized pea French fries
(Pea starch & pea flour)
(Prototype D)

A. Physiochemical characteristics

The physiochemical effects of using pea starch and pea flour in French fry batter are presented in Table 17. Split pea flour used with either starch combination (prototypes A and B) thickened the batter compared to the control; however, batter viscosity was acceptable for processing and hydration was the same as the control (1 dry: 1.45 water). Whole pea flour used with either starch combination (prototypes C and D) thickened the batter excessively; thus, these samples were thinned to a target viscosity of 525 centipoise (25 seconds Stein Cup) by hydrating 1 part dry batter mix with 1.65 parts water. Thinned whole pea flour batters still showed higher batter pick-up ($p \le 0.05$) than the split pea batters and control.

Split pea flour French fries (A and B) had higher par fry yield ($p \le 0.05$) than control and whole pea flour French fries (C and D). There was no difference in par fry yield between the whole pea flour and 100% pea starch battered French fries (D) and the control; however, par fry yield of fries containing whole pea flour with only cook-up starch replacement (C) was significantly lower than all test samples and the control.

Based on par fried French fry total fat data (Table 25, pg. 39), both split pea flour prototypes (A and B) and both whole pea flour prototypes (C and D) contained more fat (7.0 - 7.1%) than control (6.2% fat). Also, split pea flour prototypes (A and B) were observed to have less crumb production compared to the whole pea flour prototypes during par frying which can be attributed to their significantly lower batter pick-up. Thus, the higher par fry yield of the split pea flour samples can be attributed to increased fat pick-up and crumb retention. No differences for cook yield were observed.

French fries made with whole pea flour and pea starch (C and D) lost similar levels of weight during heat lamp exposure compared to the control; however, battered fries made with Fiesta™ split pea flour (pea flour with lowest WHC) and 100% pea starch replacement (prototype B) lost significantly more weight (1.8%) than the control and other test samples after 30 minutes holding under a heat lamp. Additionally, both samples using 100% pea starch in combination with pea flour (prototypes B and D) showed slightly lower total moisture content than the partial starch replacement prototypes (A and C) and the control. This suggests that pea starch replacement of both cook-up and instant corn starch in French fry batter could have an effect on moisture content and weight retention in the finished product. Thus, it is best to select pea flour that has a good WHC to use in combination with native pea starch.

Table 17: Effect of pea starch and pea flour on the physiochemical characteristics of optimized battered French fries

	Control[1]	**A[2]**	**B[3]**	**C[4]**	**D[5]**	**P-value**
Cook-up Starch	Corn	Pea	Pea	Pea	Pea	
Instant Starch	Corn	Corn	Pea	Corn	Pea	
Flour	Wheat/Corn	Split Pea	Split Pea	Whole Pea	Whole Pea	
Batter Viscosity[6], centipoises	423.5[a]	567.5[bc]	613.0[c]	576.5[bc]	509.0[b]	0.023
Batter Pick-up, %	14.89[a]	14.44[a]	14.49[a]	18.44[b]	19.14[b]	0.030
Par fry Yield, %	84.73[b]	90.31[c]	90.85[c]	77.01[a]	82.06[b]	0.001
Crumb Production, %	1.92[ab]	1.17[a]	1.64[ab]	3.27[b]	3.24[b]	0.013
Cook Yield, %	72.32	74.72	69.24	75.50	71.16	0.416
Weight Loss, %	2.52[a]	2.56[a]	4.35[b]	2.15[a]	2.29[a]	0.002
Total Moisture[7], %	65.90	64.90	64.20	65.10	63.9	--

Means represent quadruplicate observations
[1] Control made with all purpose and soft wheat flour and modified corn starches ; 1.4 parts water: 1 part dry
[2] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified corn starch; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch and modified corn starch; 1.65 parts water: 1 part dry
[5] Made with Best™ whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry
[6] Measured with Brookfield viscometer (ModelRVDV-11 +PRO) with spindle 3 at 100RPM
[7] SGS Canada Inc. method 03-01-SLM-FD-0009 on par fried French fries
[a, b, c] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Table 18 shows that even after temperature abuse, French fries coated with batters containing pea starch and pea flour maintained cook yield and moisture levels similar to the control. It is important to note that the differences observed for weight loss prior to freeze-thaw cycles were not present after temperature abuse.

Table 18: Effect of pea starch and pea flour on the physiochemical characteristics of temperature abused optimized battered French fries

	Control[1]	A[2]	B[3]	C[4]	D[5]	P-value
Cook-up Starch	Corn	Pea	Pea	Pea	Pea	**P $\leq$ .05**
Instant Starch	Corn	Corn	Pea	Corn	Pea	
Flour	Wheat/Corn	Split Pea	Split Pea	Whole Pea	Whole Pea	
Cook Yield, %	72.97	75.96	74.58	73.13	69.87	0.665
Weight Loss, %	2.17	2.08	3.10	1.89	2.09	0.494
Total Moisture[6], %	65.40	65.30	64.10	64.20	65.40	--

Means represent quadruplicate observations
[1] Control made with all purpose and soft wheat flour and modified corn starches (National Starch) ; 1.4 parts water: 1 part dry
[2] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified corn starch; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[4] Made with Best Cooking Pulses whole pea flour, Accu-Gel™ native pea starch and modified corn starch; 1.65 parts water: 1 part dry
[5] Made with Best Cooking Pulses whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry
[6] SGS Canada Inc. method 03-01-SLM-FD-0009 on par fried French fries

B. Sensory evaluation

Table 19 shows battered French fries made with pea starch and pea flour in the coating were similar to the control for overall quality (slightly to moderately high), moistness (slightly dry to slightly moist), crispness (slightly soggy to moderately crispy), baked potato flavour (slight), off-flavour (none) and colour (0.5 – 1.0). Prototypes (C and D) made with thinned whole pea flour batters, visually had rougher surface texture ($p \leq 0.05$) than the control and prototype A. Additionally, prototype D (whole pea flour and 100% pea starch) was rated significantly more tender at 5 minutes compared to the control and the split pea flour with 100% pea starch French fries (B). Sensory panellist ratings suggest that French fries made with Fiesta™ split pea flour and 100% pea starch (sample B) were the lowest in overall quality due to a significantly tougher external bite and a slight dryness.

Table 19: Effect of pea starch and pea flour on sensory characteristics of optimized battered French fries

	Time[1]	Control[2]	A[3]	B[4]	C[5]	D[6]	P-value
Cook-up Starch		Corn	Pea	Pea	Pea	Pea	
Instant Starch		Corn	Corn	Pea	Corn	Pea	
Flour		Wheat/Corn	Split Pea	Split Pea	Whole Pea	Whole Pea	
Colour	5	0.50	0.50	0.75	1.10	0.83	0.300
0=light; 6=dark	30	1.08	0.30	0.50	0.90	0.83	0.070
Surface Texture	5	2.67[b]	3.40[b]	2.83[b]	1.60[a]	1.60[a]	0.000
1=rough; 4=smooth	30	2.60[ab]	3.50[b]	2.40[ab]	2.00[a]	1.60[a]	0.003
Exterior Bite	5	4.20[b]	3.00[ab]	5.25[b]	3.80[ab]	2.80[a]	0.043
1=tender; 8=tough	30	5.80	4.00	5.50	5.00	5.00	0.114
Crispness	5	6.50	5.60	5.17	6.00	6.00	0.215
1=soggy; 8=crispy	30	5.50	5.00	4.50	5.20	5.50	0.531
Moistness	5	5.33	4.20	4.00	5.00	4.50	0.528
1=dry; 8=moist	30	5.33	4.60	4.33	4.80	5.50	0.594
Off Flavour	5	1.17	1.00	1.00	1.00	1.17	0.628
1=none; 4=extreme	30	1.00	1.00	1.00	1.00	1.00	0.999
Potato Flavour	5	2.00	2.00	2.50	1.80	1.83	0.537
1=none; 4=extreme	30	1.67	2.00	2.17	2.00	1.67	0.816
Overall Quality	5	5.50	6.20	4.67	5.60	6.00	0.125
1=low; 8=high	30	4.83	5.20	4.00	5.20	5.17	0.333

Means represent data from a 13-person trained sensory panel
[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Control made with all purpose and soft wheat flour and modified corn starches (National Starch); 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.4 parts water: 1 part dry
[4] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[5] Made with Best™ whole pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.65 parts water: 1 part dry
[6] Made with Best™ whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Sensory characteristics of French fries containing pea starch and pea flour were not significantly affected by temperature abuse when compared to temperature abused control French fries (Table 20). Generally, French fries containing pea flour had increased crispness and tenderness compared to the control fries after temperature abuse. Fries made with whole pea flour and pea starch were significantly more tender and smoother on their surface than the control at the five minute hold time. All samples were considered to have slightly high to moderately high overall quality.

Table 20: Effect of pea starch and pea flour on the sensory characteristics of temperature abused optimized battered French fries

	Time[1]	Control[2]	A[3]	B[4]	C[5]	D[6]	P-value
Cook-up Starch		Corn	Pea	Pea	Pea	Pea	
Instant Starch		Corn	Corn	Pea	Corn	Pea	
Flour		Wheat/Corn	Split Pea	Split Pea	Whole Pea	Whole Pea	
Colour	5	0.90	1.10	0.90	1.20	0.80	0.781
0=light; 6=dark	30	0.90	0.60	0.80	1.00	1.00	0.709
Surface Texture	5	3.50[b]	2.80[ab]	3.50[b]	1.80[a]	2.25[a]	0.001
1=rough; 4=smooth	30	3.00[abc]	2.80[abc]	3.50[c]	2.25[ab]	2.25[ab]	0.006
Exterior Bite	5	3.25[b]	1.50[a]	2.00[ab]	2.25[ab]	1.75[ab]	0.012
1=tender; 8=tough	30	6.00	6.00	4.50	4.50	4.50	0.051
Crispness	5	5.80	5.20	6.40	6.00	6.40	0.582
1=soggy; 8=crispy	30	4.00	4.20	5.60	5.60	5.60	0.052
Moistness	5	5.00	6.00	5.60	5.60	5.60	0.820
1=dry; 8=moist	30	4.40	4.80	5.80	4.60	4.20	0.377
Off Flavour	5	1.00	1.00	1.00	1.00	1.00	0.999
1=none; 4=extreme	30	1.00	1.00	1.00	1.00	1.00	0.999
Potato Flavour	5	1.80	2.00	2.00	2.00	2.00	0.992
1=none; 4=extreme	30	2.00	2.20	1.80	1.80	1.80	0.510
Overall Quality	5	6.00	5.80	5.60	6.60	6.40	0.407
1=low; 8=high	30	4.60	4.60	5.60	5.40	5.00	0.517

Means represent data from a 5-person trained sensory panel

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs

[2] Control made with all purpose and soft wheat flour and modified corn starches (National Starch); 1.4 parts water: 1 part dry

[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.4 parts water: 1 part dry

[4] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry

[5] Made with Best whole pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.65 parts water: 1 part dry

[6] Made with Best whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry

[a, b, c] means with differing superscripts are significantly different ($p \leq .05$)

C. Objective tests

Instrumental texture analysis was used to assess French fry crunchiness and overall firmness based on the initial slope (crunchiness) and total energy (firmness) required to cut through the fries after 3 and 30 minutes of holding in a food warmer. Table 21 shows there were no significant differences between the control and pea treatments in French fry instrumental crunchiness after 3 minutes of holding in the food warmer; this was also observed by trained sensory panellists. Over time (3 to 30 minutes), the coating on all French fries was observed to be crunchier. Overall firmness was expected to increase from 3 to 30 minutes and the control fry values did; however, only pea prototypes (B and C) increased in firmness over time similar to the control. The other pea prototypes (A and D) decreased in firmness over time and at 30 minutes, prototype A was significantly less firm and less crunchy than the control and prototype D.

Table 21: Effect of pea starch and pea flour on the instrumental texture of optimized battered French fries

	Time[1]	Control[2]	A[3]	B[4]	C[5]	D[6]	P-value
Cook-up Starch		Corn	Pea	Pea	Pea	Pea	
Instant Starch		Corn	Corn	Pea	Corn	Pea	
Flour		Wheat/Corn	Split Pea	Split Pea	Whole Pea	Whole Pea	
Crunchiness[7]	**3 min**	1116.59	727.13	992.73	631.19	861.45	0.182
Overall Firmness[8]		9786.97	9032.58	8907.39	8045.90	11046.33	0.069
Crunchiness[7]	**30 min**	1250.26[a]	771.57[d]	1178.56[abc]	863.47[cd]	1225.02[ab]	0.002
Overall Firmness[8]		12011.79[a]	7394.52[b]	9634.48[ab]	9843.53[ab]	10465.63[a]	0.007

Means represent triplicate observations
[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Control made with all purpose and soft wheat flour and modified corn starches (National Starch) ; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.4 parts water: 1 part dry
[4] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[5] Made with Best whole pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.65 parts water: 1 part dry
[6] Made with Best whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry
[7] Crunchiness determined by the initial gradient (slope); higher value= crunchier
[8] Overall firmness determined by the area under the texture analysis curve; higher value=firmer
[a, b, c, d] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Temperature abused French fries containing split pea flour (A and B) were significantly less crunchy and less firm at 3 minutes than the control (Table 22). However after 30 minutes of holding temperature abused fries under a warmer, no significant difference in instrumental texture were observed.

Table 22: Effect of pea starch and pea flour on the instrumental texture of temperature abused optimized battered French fries

	Time[1]	Control[2]	A[3]	B[4]	C[5]	D[6]	P-value
Cook-up Starch		Corn	Pea	Pea	Pea	Pea	
Instant Starch		Corn	Corn	Pea	Corn	Pea	
Flour		Wheat/Corn	Split Pea	Split Pea	Whole Pea	Whole Pea	
Crunchiness[7]	**3 min**	904.83[b]	763.49[a]	626.14[a]	871.55[ab]	946.28[ab]	0.009
Overall Firmness[8]		10021.22[b]	7906.42[a]	7968.13[a]	9955.62[b]	9663.77[b]	0.006
Crunchiness[7]	**30 min**	982.14	804.89	714.01	997.78	987.68	0.281
Overall Firmness[8]		10328.31	8375.14	9304.25	10046.52	8594.28	0.216

Means represent triplicate observations
[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Control made with all purpose and soft wheat flour and modified corn starches (National Starch) ; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified corn starch; 1.4 parts water: 1 part dry
[4] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[5] Made with Best whole pea flour, Accu-Gel™ native pea starch and modified corn starch; 1.65 parts water: 1 part dry
[6] Made with Best whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry
[7] Crunchiness determined by the initial gradient (slope)
[8] Overall firmness determined by the area under the texture analysis curve
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

There were no significant differences in L*, a* and b* values between the control and pea treatments; although there were a few differences between the pea treatments in a* and b* values (Table 23). Whole pea flour fries (samples C and D) were generally more red and more yellow than control and split pea flour fries (samples A and B).

Table 23: Effect of pea starch and pea flour on the instrumental colour of optimized battered French fries

	Time[1]	Control[2]	A[3]	B[4]	C[5]	D[6]	P-value
Cook-up Starch		Corn	Pea	Pea	Pea	Pea	
Instant Starch		Corn	Corn	Pea	Corn	Pea	
Flour		Wheat/Corn	Split Pea	Split Pea	Whole Pea	Whole Pea	
L* **(0=black; 100=white)**	**5 min**	55.37	54.94	52.74	55.33	55.19	0.079
a* **(Pos=red; Neg=green)**		1.27^{ab}	1.15^{ab}	0.99^{a}	1.62^{ab}	2.72^{b}	0.037
b* **(Pos=yellow; Neg=blue)**		14.42^{ab}	12.64^{a}	14.03^{ab}	16.52^{b}	16.45^{ab}	0.029
L* **(0=black; 100=white)**	**30 min**	57.13	54.44	57.37	57.33	55.26	0.091
a* **(Pos=red; Neg=green)**		0.41	0.43	0.40	1.62	1.94	0.232
b* **(Pos=yellow; Neg=blue)**		17.50	14.48	15.43	17.97	18.37	0.256

Means represent 12 observations
[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Control made with all purpose and soft wheat flour, corn flour & modified corn starches; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified corn starch; 1.4 parts water: 1 part dry
[4] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[5] Made with Best whole pea flour, Accu-Gel™ native pea starch and modified corn starch; 1.65 parts water: 1 part dry
[6] Made with Best whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

During thawing (temperature abuse), moisture migrates into the coating and can result in a finished product with a darker colour. After temperature abuse, sample A was the most unlike the control in colour; significantly less red and less yellow at both 5 and 30 minute evaluations. These instrumental findings for colour are similar to sensory panellist ratings (Table 19 and 20).

Table 24: Effect of pea starch and pea flour on the instrumental colour of temperature abused optimized battered French fries

	Time[1]	Control[2]	A[3]	B[4]	C[5]	D[6]	P-value
Cook-up Starch		Corn	Pea	Pea	Pea	Pea	
Instant Starch		Corn	Corn	Pea	Corn	Pea	
Flour		Wheat/Corn	Split Pea	Split Pea	Whole Pea	Whole Pea	
L* **(0=black; 100=white)**	**5 min**	54.32	56.18	55.05	56.77	56.58	0.112
a* **(Pos=red; Neg=green)**		2.84^{a}	0.57^{b}	2.29^{ab}	1.69^{ab}	1.62^{ab}	0.035
b* **(Pos=yellow; Neg=blue)**		22.09^{a}	18.85^{b}	22.09^{a}	20.64^{ab}	20.79^{ab}	0.038
L* **(0=black; 100=white)**	**30 min**	58.43	58.90	58.09	58.07	56.36	0.198
a* **(Pos=red; Neg=green)**		2.20^{a}	-0.78^{b}	0.70^{ab}	1.29^{ab}	2.07^{a}	0.003
b* **(Pos=yellow; Neg=blue)**		21.58^{a}	17.60^{b}	19.96^{ab}	21.22^{a}	19.42^{ab}	0.003

Means represent 12 observations
[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Control made with all purpose and soft wheat flour and modified corn starches; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.4 parts water: 1 part dry
[4] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[5] Made with Best™ whole pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.65 parts water: 1 part dry
[6] Made with Best™ whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry
[a, b] Means with differing superscripts are significantly different ($p \leq .05$)

2.7. Nutritional composition

In the starch replacement phase, nutritional differences observed between control (cook-up corn starch) and test (pea starch) French fries were small. Thus, only the nutritional composition of the optimized par-fried French fries (per 100g) is reported in Table 25. Whole and split pea flours both contain more protein and dietary fibre than wheat flour but batters containing whole pea flour were hydrated to a higher ratio than those with wheat flour and/or split pea flour so the nutritional differences were not as large as if the batters were hydrated at the same ratio. The protein content of French fries containing pea starch and pea flour was slightly higher than the control because pea flour contains more protein (22-24%) than wheat flour (8-13%). The total dietary fibre of the French fries containing pea flours was similar to the amount found in the control. French fries with whole pea flour (C and D) were noted for having more calcium than the control and split pea flour French fries (A and B). French fries prepared with split pea flour were noted for having lower sodium than the control and French fries made with whole pea flour. Ingredient specification sheets indicated that whole pea flour contained more calcium and sodium than split pea flour; this supports nutritional results observed in French fries containing whole or split pea flour.

Table 25. Nutritional composition of optimized par fried French fries per 100g[a]

		Control[1]	A[2]	B[3]	C[4]	D[5]
Energy	kcal	158	174	172	170	176
Protein (Nx6.25)	g	2.2	2.3	2.5	2.5	2.6
Fat	g	6.2	7.1	7.1	7.1	7.0
Calories from Fat	kcal	47	64	64	64	63
Saturated Fat	g	0.5	0.6	0.6	0.6	0.6
Monounsaturated Fat	g	3.3	4.5	4.5	4.5	4.5
Polyunsaturated Fat	g	1.4	2.0	2.0	1.9	1.9
Trans Fat	g	<0.1	<0.1	<0.1	<0.1	<0.1
Cholesterol	mg	<1.0	<1.0	<1.0	<1.0	<1.0
Carbohydrates	g	25.5	25.3	24.4	24.0	25.7
Total Sugar	g	<0.1	<0.1	<0.1	<0.1	<0.1
Total Dietary Fibre	g	3.0	2.7	2.6	3.2	3.1
Sodium	mg	240.4	191.7	186.4	244.0	236.6
Calcium	mg	7.9	7.8	7.6	11.4	11.2
Iron	mg	0.5	0.5	0.5	0.5	0.5
Moisture	g	65.9	64.2	64.9	65.1	63.5
Ash	g	1.2	1.1	1.1	1.3	1.2
Vitamin A	IU	<10	<10	<10	<10	<10
Vitamin C	mg	11.5	11.2	9.0	10.0	9.7

[1] Control made with all purpose and soft wheat flour, corn flour & modified corn starches ; 1.4 parts water: 1 part dry
[2] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.65 parts water: 1 part dry
[5] Made with Best™ whole pea flour and Accu-Gel™ native pea starch; 1.65 parts water: 1 part dry
[a] Results were obtained from SGS Laboratories (Vancouver, BC)

Nutritional facts panels for the control and optimized pea ingredient prototypes are shown in Figure 2. According to the Canadian Guide to Food Labeling and Advertising (Schedule M, Table 6.1), the reference amount for frozen French fries is 85g and the serving size is 70-100g. Pea starch did not affect the nutritional composition of battered, par fried French fries. However, optimized battered French fries made with split pea flour and 100% pea starch (prototype B) resulted in a 1g increase in total protein, 1g increase in total fat, 10 calorie increase, and a 50 mg reduction in sodium (~20%) per 100g compared to control fries. Optimized battered French fries made with whole pea flour and 100% pea starch (sample D) resulted in a 1g increase in total protein, 1g increase in total fat, and an increase of 20 calories per 100g compared to control fries.

Figure 2: Nutritional facts panels for control and test samples of battered, par fried, frozen French fries

Control Battered French Fries (Corn Starch & Wheat & Corn Flours)

Nutrition Facts Valeur nutritive Serving Size (100 g) / Portion (100 g)	
Amount Teneur	% Daily Value % valeur quotidienne
Calories / Calories 160	
Fat / Lipides 6 g	**9** %
Saturated / saturés 0.5 g + Trans / trans 0 g	**3** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 240 mg	**10** %
Carbohydrate / Glucides 26 g	**9** %
Fibre / Fibres 3 g	**12** %
Sugars / Sucres 0 g	
Protein / Protéines 2 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	20 %
Calcium / Calcium	0 %
Iron / Fer	4 %

Optimized Battered French Fries (100% Pea Starch & Split Pea Flour)

Nutrition Facts Valeur nutritive Serving Size (100 g) / Portion (100 g)	
Amount Teneur	% Daily Value % valeur quotidienne
Calories / Calories 170	
Fat / Lipides 7 g	**11** %
Saturated / saturés 0.5 g + Trans / trans 0 g	**3** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 190 mg	**8** %
Carbohydrate / Glucides 24 g	**8** %
Fibre / Fibres 3 g	**12** %
Sugars / Sucres 0 g	
Protein / Protéines 3 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	15 %
Calcium / Calcium	0 %
Iron / Fer	4 %

Optimized Battered French Fries (100% Pea Starch & Whole Pea Flour)

Nutrition Facts Valeur nutritive Serving Size (100 g) / Portion (100 g)	
Amount Teneur	% Daily Value % valeur quotidienne
Calories / Calories 180	
Fat / Lipides 7 g	**11** %
Saturated / saturés 0.5 g + Trans / trans 0 g	**3** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 240 mg	**10** %
Carbohydrate / Glucides 26 g	**9** %
Fibre / Fibres 3 g	**12** %
Sugars / Sucres 0 g	
Protein / Protéines 3 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	15 %
Calcium / Calcium	2 %
Iron / Fer	4 %

2.8. Cost implications

Table 26 shows pea starch was higher priced than corn starch used in the control batter dry mix. Pea starch was estimated to cost an additional $0.11-0.13 CDN/lb over corn starch, whereas, pea flour was estimated to be cheaper than wheat and corn flours. In the optimized pea French fry batters, xanthan gum and Maillose® caramel colour, two expensive ingredients, were removed from the formulation because pea flour had greater colour development and thickening than wheat flour.

Table 26: Pre-dust and batter ingredient price comparison

Ingredient	CDN $/lb
Wheat flour – soft, bleached*	$0.41
Wheat flour – all purpose*	$0.43
Corn flour – yellow*	$0.45
Pea Flour**	$0.40
Modified Corn Starch*	$0.82
Instant Corn Starch*	$0.84
Native Pea Starch**	$0.95
Xanthan Gum*	$4.88
Maillose® Colour*	$11.95

* Commodity price estimates per national vendors, March 2011
** Average price based on Canadian pea fraction suppliers, August 2011

Table 27 shows the estimated cost of each hydrated batter, as well as the cost compared to the control batter. The cost to implement the use of pea starch was less than one cent per pound of hydrated batter. Optimized pea batters made with whole pea flour showed a cost savings of $0.02 to $0.03 CDN/lb of hydrated batter (sample C and D, respectively) compared to the control, primarily due to an increased hydration level. It is important to note that samples A and B, made with split pea flour, were slightly thicker than the control batter when hydrated at the same rate (1.4 parts water to 1 part dry); 560-615 centipoise versus 430 centipoise, respectively. If batters A and B were thinned to a similar viscosity as the control, there would be potential cost savings. Additionally, Best™ split pea flour (prototypes not selected, data not shown) also resulted in thicker batters and would likely generate cost savings due to increased hydration. It is key to note that all test batters were thicker than the control; therefore, batter viscosity optimization should be investigated to achieve optimum water hydration and minimize batter ingredient costs.

Table 27: Hydrated French fry batter cost estimate (CDN $/lb)

	Control[1]	Cook-up Pea Starch Replacement[2]	Optimized French Fry Batter			
			A[3]	B[4]	C[5]	D[6]
Cook-up Starch	Corn	Pea	Pea	Pea	Pea	Pea
Instant Starch	Corn	Corn	Corn	Pea	Corn	Pea
Flour	Wheat	Wheat	Split Pea	Split Pea	Whole Pea	Whole Pea
Hydrated Batter CDN Price/lb	$0.231	$0.238	$0.220	$0.229	$0.198	$0.206
Price Difference from Control	$.000	$0.007	-$0.011	$-0.002	$ -0.033	$ -0.025

[1] Control made with all purpose and soft wheat flour, corn flour & modified corn starches ; 1.4 parts water: 1 part dry
[2] Made with all purpose and soft wheat flour and Accu-Gel™ native pea starch and instant corn starch; 1.4 parts water: 1 part dry
[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.4 parts water: 1 part dry. Maillose® and xanthan gum removed
[4] Made with Fiesta™ split pea flour and Accu-Gel™ native pea starch; 1.4 parts water: 1 part dry. Maillose® and xanthan gum removed
[5] Made with Best™ whole pea flour, Accu-Gel™ native pea starch and modified instant corn starch; 1.65 parts water: 1 part dry. Maillose® and xanthan gum removed

2.9. Conclusions – French fry

French fry batters containing wet fractionated native pea starch, Accu-Gel™, or dry fractionated native pea starch, Starlite™, generally performed at an acceptable level compared to the control batter containing chemically modified, wet milled corn starch. Pea starch did not affect the nutritional composition of battered par fried French fries. Battered French fries were evaluated before and after temperature abuse to assess the functionality of the pea starches. No differences were observed between battered French fries containing pea or corn starch in par fried yield, cook yield, and residual crumb production in the fryer.

Pea starch increased batter viscosity ($p \leq 0.05$) and batter pick-up compared to corn starch batter; however, batter containing pea starch was still process capable. Dry milled starch, Starlite™ produced batters with significantly more viscosity than batters with wet milled starch, Accu-Gel™ or corn starch.

Battered French fries made with pea starch (Accu-Gel™ or Starlite**™**) in the coating were similar to control French fries made with corn starch for the following sensory characteristics: overall quality (slightly to moderately high), exterior bite (slightly to moderately tender), baked potato flavour (slight) and off-flavour (none). Sensory panellist ratings suggested that French fries made with Accu-Gel™ pea starch were more similar to control French fries than fries containing Starlite™ pea starch which produced crisper and more golden fries with a slightly rougher surface texture after 5 and 30 minutes holding in a food warmer versus control and Accu-Gel™ samples. Additionally, panellists rated French fries made with Accu-Gel™ pea starch as more moist (moderately moist versus slightly dry) after 30 minutes of holding in a food warmer compared to the control and the Starlite™ samples. The cost to implement the use of pea starch was less than one cent per pound of hydrated batter although increasing batter hydration could improve the economics of pea starch use.

Pea starch and pea flour were utilized in the development of optimized GF battered French fries. Due to increased thickening and colour development from pea flours, xanthan gum and Maillose® caramel colour were removed from the batter formulation resulting in a cleaner label. Pea hull fibre and pea protein isolate addition were assessed but they did not improve sensory or nutritional qualities of the battered French fries.

Pea flour that is equal to or less than 425 microns in size with a WHC equal to or less than 100% would reduce excess batter viscosity. Pea flour with a larger particle size or one with higher WHC would require batter hydration to be increased to maintain a workable batter viscosity (15-40 seconds Stein Cup / 400-600 centipoise).

Increased hydration and gum and caramel colour removal may allow for ingredient cost savings as estimates in this study show; however, finished product quality must be considered. Whole pea flour hydrated at 1 part dry to 1.65 parts water (compared to the control 1:1.4) showed a hydrated batter cost savings of $0.02 to $0.03 CDN /lb.

Battered French fries with pea starch and split pea flour (prototype B) lost significantly more weight over 30 minute holding period than other prototypes. However, after temperature abuse, weight loss was similar between French fry prototypes. Thus, differences in weight loss among French fries became less noticeable after temperature abuse.

Optimized pea battered French fries made with split or whole pea flour and pea starch resulted in 1g increase in fibre, 1g increase in protein, 1g increase in fat and an increase of 10 to 20 calories per 100g compared to the control. GF French fry batters can be successfully prepared using native pea starch and pea flour as 100% replacements for traditional modified corn starch and wheat and corn flours.

2.10. Opportunities & challenges – French fries

Opportunities and challenges associated with utilizing pea ingredients in French fry batters or similar food products.

Opportunities for pea ingredients:

1) Gluten-free: pea starch and pea flour can be used in combination to develop GF coated products.

2) Cleaner label: pea starch and pea flour can both be used to replace functional ingredients (Maillose® caramel colour and xanthan gum), thus, simplifying the ingredient list and providing more 'green' final products.

3) Enhanced colour: dry milled pea starch and pea flour both contribute a golden colour to fried products and can replace corn flour and Maillose® caramel colour.

4) Ingredient cost reduction: pea starch and pea flour can both replace expensive ingredients (xanthan gum and Maillose® caramel colour) and offset the slightly higher pea starch cost for an overall cost reduction. Potential for further cost reduction exists through increased batter hydration.

5) Improved nutrient profile: whole pea flour can increase calcium and split pea flour can reduce sodium of final products.

6) Enhanced texture: dry milled pea starch can increase crispness of the fried product.

7) Batter viscosity: pea starch and pea flour both increase batter viscosity, thus, gum replacement and subsequent cost reduction is possible. Greater batter viscosity is obtained with dry milled starch and also with whole pea flour.

Challenges for pea ingredients:

1) Batter viscosity: pea starch and pea flour both require increased hydration to obtain a process capable batter.

2) Fat absorption: pea starch combined with pea flour slightly increased fat uptake during par frying.

2) Milling process: dry milled pea starch created batters with higher viscosity than wet milled starch.

3) Slightly higher cost: currently, pea starch is more expensive than corn starch but potential for increased batter hydration rates could offset the higher price per pound.

3.0. MOZZARELLA STICKS

3.1. Experimental design

Similar to the French fry application, the mozzarella stick study was split into two phases: (1) starch replacement and (2) optimized replacement of starch, flour, gluten, and gum with pea ingredients. However in the mozzarella application, two optimized prototypes were produced: (1) a pea prototype with wheat crumbs and (2) a GF version containing GF crumbs. Two optimized pea prototypes were prepared because quality of the GF mozzarella stick was lower than the control when denser commercially available GF bread crumbs were substituted for traditional wheat bread crumbs.

In the starch replacement phase, both pea starches were independently studied. Breaded mozzarella sticks were prepared using a six step coating system: batter, pre-dust, batter, pre-dust, batter, breader. In order to avoid blow outs, coated mozzarella sticks require a high number of coating steps and cheese with a high melt temperature; thus, a six step coating system and high melt cheese were used. In the control mozzarella stick coating system, the pre-dust and batter contained cook-up corn starch and the breader contained instant corn starch. Preliminary trials examined the replacement of only cook-up corn starch with pea starch in the pre-dust and batter while leaving instant corn starch in the breader but similar results were observed whether one or both corn starches were replaced. Thus, pea starch (Accu-Gel™ and Starlite™) was evaluated in mozzarella stick coatings by fully replacing both cook-up and instant corn starches to maximize the use of pea starch.

In the optimization phase, the most successful pea starch from the starch replacement phase was used in combination with other pea ingredients to develop both optimized pea mozzarella sticks. Three pea flours, three pea hull fibres, and one pea protein isolate, all commercially available in Canada, were evaluated as replacements for corn starch, wheat flour, corn flour, wheat gluten, and guar gum. Three brands of retail GF bread crumbs were evaluated as replacements for commercial wheat bread crumbs and cracker meal containing gluten. The pea fraction suppliers and fractionation method used are described in Chapter 2 (Table 1).

3.2. Materials

3.2.1. Mozzarella sticks

Mozzarella sticks (pizza string cheese) with a high melting point (450°F) to minimize cheese blow outs were supplied by Saputo Foods Ltd. of Winnipeg, MB. The cheese sticks were extruded and individually quick frozen (1/2” diameter and 3 1/6” length) by Saputo and stored in lined boxes in the FDC pilot plant freezer until required for trials. The moisture and fat content of the mozzarella sticks were 52% and 20%, respectively. Prior to coating, the mozzarella sticks were thawed overnight in a sealed bag in the refrigerator. The cheese sticks were then manually cut in half to a length of approximately 1½”. The cheese was semi-soft, ivory coloured with a milky, slightly salty flavour and a moisture-rich, rindless body with a springy firmness. Figure 3 displays the nutrition facts table provided by Saputo Foods for the mozzarella sticks used. The ingredient listing for the mozzarella stick is stated as “Pasteurized milk, modified milk ingredients, bacterial culture, salt, calcium chloride, microbial enzyme”.

Figure 3. Nutrition facts table for Saputo mozzarella sticks

Nutrition Facts
Valeur nutritive
Per 3 cm cube (30 g)
par cube de 3cm (30 g)

Amount Teneur	% Daily Value % valeur quotidienne
Calories / Calories 80	
Fat / Lipides 6 g	**9** %
Saturated / saturés 4 g + Trans / trans 0,2 g	**21** %
Cholesterol / Cholestérol 20 mg	
Sodium / Sodium 250 mg	**10** %
Carbohydrate / Glucides 0 g	**0** %
Fibre / Fibres 0 g	**0** %
Sugars / Sucres 0 g	
Protein / Protéines 7 g	
Vitamin A / Vitamine A	6 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	15 %
Iron / Fer	0 %

3.2.2. Coating system

Commercial cheese stick coating dry mixes were supplied by Newly Weds Foods of Mississauga, ON. Table 28 shows the “Base” supplied by Newly Weds Foods and the control coating formulation of the pre-dust, batter, and breader. Both control and test coating dry mixes were blended using a Hobart food mixer with a wire whisk attachment to ensure uniformity. Viscosity of the hydrated batter was measured with a Stein Cup (seconds of flow from full to empty) to mimic the industry method, as well as, with a Brookfield viscometer (Model RVDV-11 +PRO) with spindle 3 at 100 RPM for 15 seconds for better accuracy.

Table 28. Control pre-dust, batter, and breader formulas for coating mozzarella sticks

PRE-DUST		Seasoning Blend Formula	Dry Mix Formula	
		%		
Base	Salt - hygrade	2.00	3.58	
	Black pepper, ground	0.30		
	Garlic powder	0.50		
	Onion powder	0.60		
	Celery seed, ground	0.10		
	Thyme, ground	0.08		
Cracker meal		----	70.27	
Wheat flour - soft, unbleached		----	11.00	
Wheat gluten		----	6.00	
Oil - vegetable, non hydrogenated		----	0.15	
Starch - cook-up, corn, modified		----	9.00	
	Pre-dust Dry Mix Formula		**100.00**	
BATTER		**Seasoning Blend Formula**	**Dry Mix Formula**	**Hydrated Formula**
		%		
Base	Salt - dendritic	4.00	7.50	2.50
	Sugar - fine, white, cane	2.50		
	Bakin powder – SAPP*	1.00		
Wheat flour - soft, unbleached		----	15.00	5.00
Wheat flour - all purpose, unbleached		----	37.25	12.42
Corn flour - yellow		----	20.00	6.67
Gum - guar		----	0.25	0.08
Starch - cook-up, corn, modified		----	20.00	6.67
	Batter Dry Mix Formula		**100.00**	
Water (4°C)				66.66
	Hydrated Batter (2 parts water : 1 part dry mix)			**100.00**
BREADER		**Seasoning Blend Formula**	**Dry Mix Formula**	
		%		
Base	Salt – dendritic	1.80	2.85	
	Celery seed, ground	0.06		
	Sage, ground	0.06		
	Marjoram, ground	0.06		
	Savory, ground	0.06		
	Garlic powder	0.21		
	Onion powder	0.42		
	Black pepper, ground	0.18		
Wheat flour - soft, unbleached		----	35.04	
Wheat flour - all purpose, unbleached		----	12.00	
Bread crumb - American style		----	6.00	
Bread crumb - Japanese Panko style		----	40.00	
Oil - vegetable, non-hydrogenated		----	0.21	
Starch - instant, corn, modified		----	3.90	
	Breader Dry Mix Formula		**100.00**	

*Sodium acid pyrophosphate

3.3. Sample preparation

Pre-dust and breader mixes were spread onto parchment lined trays. Cold water (4°C) was added to the batter and mixed with an electric mixer (Sunbeam Mixmaster) for one minute at medium speed and was allowed to sit for 10 minutes over ice to fully hydrate. Thawed cheese was immersed in batter for 10 seconds and set on a wire rack to allow any excess batter to drip off. Next, the mozzarella stick was rolled in pre-dust and manually shaken for 10 seconds; the process was then repeated. The cheese was again dipped into batter and finally rolled in the breader. Coated mozzarella sticks were par fried (Garland Deep Fryer, SF) at 193°C (380°F) for 20 seconds using non-hydrogenated canola oil (Canola Harvest). Coating pick-up was measured in duplicate using four pieces of cheese as a sample. Batch weights were taken to calculate total batch pick-up.

$$\text{Coating Pick-up (\%)} = \frac{\text{(coated weight - initial weight)}}{\text{coated weight}} \times 100$$

The capacity of the fryer is 18L. To maintain oil quality, 6L of used oil was blended with 12L of fresh oil after every eight batches. After par frying, the mozzarella sticks were drained in the basket for one minute to allow any excess oil to drip off; then transferred to parchment lined sheet pans and frozen overnight at -18°C (0°F). Mozzarella sticks were then bagged and returned to the freezer. Four batches of each treatment were prepared to eliminate processing effects and generate a larger number of "batch" observations.

$$\text{Par Fry Yield (\%)} = \frac{\text{par fry batch weight}}{\text{raw batch weight}} \times 100$$

Par fried mozzarella sticks were stored frozen for at least 14 days. An equal portion from each of the four production replicates were blended together to create a pooled sample for each treatment. For sensory and analytical testing, mozzarella sticks were fully fried at 177°C (350°F) for 90 seconds using non-hydrogenated canola oil (Canola Harvest).

Cooked weights were taken and cook yield was calculated based on frozen batch weight.

$$\text{Cook Yield (\%)} = \frac{\text{cooked batch weight}}{\text{frozen batch weight}} \times 100$$

3.4. Test methods

3.4.1. Sensory evaluation

Sensory evaluation by a trained panel was used to quantify the intensities of six attributes. A 10 person panel was trained in a two hour session to assess the sensory attributes of the coated mozzarella sticks. Category scales were used (4 points) for the following attributes: crispness, crunchiness/hardness, cheese texture, beany flavour, and overall quality (Appendix E). Colour was assessed using the Newly Weds Flour Breader Fry Colour Chart (6 points) (Appendix F). Fully fried mozzarella sticks were placed under a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs and evaluated after 5 and 45 minutes hold time. Current food service practices dictated the hold time of 45 minutes. Samples were presented in random order and labeled with random three-digit codes. The variability between mozzarella sticks was minimized by serving two mozzarella sticks per sample from a pooled sample of the four production dates. Panellists were given room temperature distilled water and unsalted crackers to cleanse their palate between samples. Three samples per session were evaluated to minimize panellist fatigue.

3.4.2. Nutritional analysis

SGS Canada Inc. (Vancouver, BC) conducted the nutritional analysis of the frozen par fried mozzarella sticks for the following components: energy, protein, fat, calories from fat, saturated fat, monounsaturated fat, polyunsaturated fat, trans-fat, cholesterol, carbohydrates, total sugar, total dietary fibre, insoluble fibre, soluble fibre, sodium, calcium, iron, moisture, ash, vitamin A, and vitamin C. Proximate analysis was also conducted on temperature abused mozzarella sticks to identify the effect of temperature abuse on the nutritional profile of coated mozzarella sticks and to support findings from the nutritional analysis of properly handled mozzarella sticks. All methods used in the analysis of the nutritional components were AOAC International approved and in compliance with Health Canada regulations.

3.4.3. Weight loss

Weight loss over time was determined by testing four randomly selected fully fried mozzarella sticks from each treatment after 30, 45, and 60 minutes of exposure to the food warmer (OHC-500 Heat Lamp). Each fully fried mozzarella stick was placed on a pre-weighed Whatman 1 filter paper (1.5 mm thick). The initial weight of the mozzarella stick was recorded. Filter papers with samples were placed (minimum of 12mm spacing) beneath the food warmer (heat lamps at maximum height of 60 cm above sample) and held for 60 minutes.

$$\text{Weight loss (\%) after ``x'' minutes} = \frac{\text{(cooked weight – weight @ ``x'' min)}}{\text{cooked weight}} \times 100$$

3.4.4. Moisture content

Moisture content of fully fried mozzarella sticks was determined using a modified AOAC Method 925.10. Par fried mozzarella sticks were fully fried at 350°F for 90 seconds in a commercial deep fryer. Fully fried mozzarella sticks were cooled for two minutes at room temperature; then placed into a plastic freezer bag and stored in the freezer overnight. The next day, the frozen fully fried mozzarella sticks were ground in a coffee grinder on espresso setting for one minute. Then, 2-3g of ground sample was transferred into a small metal pan. Ground mozzarella sticks were dried at 70°C for 24 hours in a conventional moisture oven (Cole Parmer); then were removed from the oven and placed in a desiccator to cool. The formula below was used to calculate the total moisture content of fully fried mozzarella sticks.

$$\text{Total Moisture \%} = \frac{\text{frozen cook weight} - \text{dried weight}}{\text{frozen cook weight}} \times 100$$

3.4.5. Instrumental texture

Texture analysis to determine coating crispness/crunchiness and overall firmness was conducted in triplicate on fully fried mozzarella sticks using a Texture Analyzer TA-X2i with the TA-42 Knife probe (45° chisel blade) attached. This cut test was designed to imitate incisor teeth cutting through the fried coating of a mozzarella stick. The total energy (area under the curve; g/sec) indicates overall firmness, whereas, the initial slope (g/sec) is an indicator of crispness/crunchiness. This method is designed to strengthen sensory results for crispness and crunchiness. Texture was measured at both 5 and 45 minutes on a $1cm^2$ piece of coating. Each mozzarella stick was cut open lengthwise, the cheese was peeled out leaving the coating intact, and the coating was then trimmed into $1cm^2$ portions. The texture analyzer was equipped with a 25kg load cell and a guillotine holder so the knife contacts the midpoint of the coating and fully cuts through. The texture analyzer was set at a test distance of 9mm, a pre-test crosshead speed of 2mm/sec until 5g of resistance was sensed, a test crosshead speed of 1mm/sec, and a post-test speed of 2mm/sec. Appendix D displays the typical curve that is generated by the texture analyzer and highlights where the measurement points for overall firmness and crispness/crunchiness.

3.4.6. Instrumental colour

Coating colour measurements were taken on four randomly selected mozzarella sticks from each treatment after 5 and 45 minutes of exposure to the food warmer. Three measurements from random locations on the surface were taken per sample; two from one side and one from the opposite side. The Konica Minolta chroma meter (Model CR-400) was used to determine L*a*b* values using an 8mm aperture. The chroma meter was calibrated with a white tile prior to testing (No. 18733148: CIE L* 97.63, a* -0.01, b* 1.60). L_0, a_0, and b_0 represent the colour parameters of the mozzarella stick at 5 minutes of holding also referred to as a standard reference, whereas, L*, a*, and b* are the corresponding colour parameters from mozzarella sticks that have been temperature abused or held 45 minutes under the food warmer. L* represents the level of brightness measured in the mozzarella stick coating. A lower L* value indicates a darker colour while a higher L* value represents a brighter colour.

After completion of the French fry study, it was brought to the researchers' attention that reporting colour as hue (H) and chroma (C) is the current industry practice. The a* and b* values are easy to measure instrumentally but they do not properly reflect what is perceived by the human eye. Colours are seen together and can instead be described as bright or dull (C) and the colour itself (H) (Fiszman, 2009). Thus for the remaining applications in this study, colour results are reported as L*, H, and C. The H and C values were calculated from a* and b* results to aid in relating instrumental results to visual assessment. To calculate the H and C values, the calculations below were used.

$$\text{Hue (H) difference} = \tan^{-1}(b^*/a^*) - \tan^{-1}(b_0/a_0)$$

$$\text{Chroma (C) difference} = [(a^*-a_0)^2 + (b^*-b_0)^2]^{0.5}$$

A lower H value corresponds to a more red coating hue while a higher H value reflects a more yellow coating hue. C is a measure of the colour intensity of the coating where higher values represent more intense colour while lower values represent less intense colour. The lower the L* value, the darker the mozzarella stick, while the higher the L* value, the brighter the coating.

3.4.7. Freeze-thaw stability

Par fried mozzarella sticks were temperature abused through two freeze-thaw cycles. Samples were removed from the storage freezer (-18°C), placed on parchment lined sheet pans, covered with cellophane wrap, and then held at room temperature. Samples were tempered to a surface temperature of 4°C then blast frozen for 20 minutes at -40°C to a surface temperature of -25°C. Samples were stored uncovered overnight in a walk-in storage freezer at -18°C. The tempering and blast freezing process was repeated the following day. Samples were then repackaged and stored in the freezer at -18°C for a minimum of 14 days. Temperature abused samples were fully fried as per methods described previously (Section 3.3) and evaluated by the same trained panel (n=10) after 5 and 45 minutes hold time.

3.5. Statistical analysis

Statistical analysis of variance (ANOVA) was carried out using Predictive Analytics SoftWare 12.0.1 for Windows (IBM Corporation, Somers, NY). Significance of treatment means were determined (α = 0.05 level of significance) with Tukey or Scheffe, depending on equality of sample size.

3.6. Results & discussion

3.6.1. Starch replacement

A. Physiochemical characteristics

In a previous project (AFC 2008F128R) and in the French fry research, it was observed that modified cook-up corn starch could be fully replaced with pea starch but the effect of replacing modified instant corn starch with native pea starch was not examined in the starch replacement trials. Preliminary trials with mozzarella sticks showed that fully replacing both cook-up and instant modified corn starches with native pea starch produced similar results as the control. Thus, to maximize pea starch use, future research examined pea starch as a 100% replacement for both cook-up and instant corn starch.

As mentioned in the French fry section, Canadian pea starch is only commercially available as native starch. There are two methods (wet and dry) of separating starch from other pea fractions. The milling process affects starch purity and the level of starch damage. Dry milling is generally known to produce a less pure starch with more starch damage; however, it is a more economical process. Chapter 2 (Table 5) compares the chemical composition of the control and test starches.

Key production indicators for commercial coating systems include batter viscosity, coating pick-up, and cook yield. Control batters ranged from 10-11 seconds, batters containing Accu-Gel™ ranged from 12-13 seconds, and batters containing Starlite™ ranged from 12-14 seconds as measured by a Stein cup. Thus, pea starch significantly thickened batter compared to the control cook-up corn starch but all test batters were process capable (Table 29). The difference in batter viscosity is likely due to the larger granule size and higher level of starch damage present in pea starches compared to corn starch. Pea containing batters had significantly higher viscosity than the control batter but no significant differences in coating pick-up or cook yield were observed between control and pea starch mozzarella sticks. In a previous project conducted by FDC regarding pea coatings on meat substrates, it was also observed that control batters had significantly lower batter viscosity than pea containing batters but coating pick-up and cook yield were not affected.

In the French fry research, dry milled Starlite™ starch batters were significantly thicker than wet milled Accu-Gel™ starch batters but in the mozzarella stick application, no significant difference in batter viscosity was observed between the pea starches. The mozzarella stick contains less starch (20%) than the French fry batter (33%); it is possible that 20% starch is insufficient to observe a measurable difference in batter viscosity due to fractionation method.

Moisture retention in coating systems is a primary concern when replacing modified starch with native starches but in the mozzarella stick application, fully fried mozzarella sticks containing dry milled Starlite™ pea starch had higher total moisture content than the control and the Accu-Gel™ mozzarella sticks. In addition, the control and both pea starches exhibited similar amounts of weight loss after heat lamp exposure. In the breaded mozzarella stick coating system, the majority of starch in the coating is in the pre-dust. Suderman (1983) noted that protein in battered/breaded coatings can aid in retaining moisture in coated food products. Starlite™ is higher in protein than other starches tested so it is hypothesized that the additional protein and high amylose in the starch may allow formation of a barrier around the cheese and under the first batter layer, as well as, between the three layers of batter which results in a final product with higher moisture content.

Table 29: Effect of pea starch on the physiochemical characteristics of coated mozzarella sticks

	Control[1]	Accu-Gel™[1]	Starlite™[1]	P-value
	Corn Starch	Pea Starch	Pea Starch	
Batter Viscosity[2], centipoises	244.75[a]	333.50[b]	336.25[b]	0.000
Coating Pick-up, %	59.83	63.33	60.22	0.051
Par fry Yield, %	102.78	102.60	102.94	0.614
Cook Yield %	92.44	92.97	93.45	0.317
Weight Loss[3] **@ 30min**, %	0.38	0.54	0.28	0.144
Weight Loss[3] **@ 45 min**, %	0.62	0.79	0.41	0.305
Weight Loss[3] **@ 60 min**, %	0.82	0.98	0.51	0.253
Moisture content[3], %	35.90[a]	35.97[a]	37.80[b]	0.006

[1] Means represent quadruplicate observations
[2] Measured with Brookfield viscometer (Model RVDV-11 +PRO) with spindle 3 at 100RPM
[3] Of fully fried mozzarella sticks
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Table 30 shows that after temperature abuse, coated mozzarella sticks containing pea starch had a significantly higher cook yield compared to the control despite similar values for total moisture content and weight loss over time. Amylose creates a more structured coating which is desirable for products that require a par fry, freeze, and full fry step and especially if products are subjected to any type of temperature abuse (Kuntz, 1997). Thus, it is hypothesized that because pea starch mozzarella sticks have more amylose than the control, they would have higher cook yields due to better coating strength.

Table 30: Effect of pea starch on the physiochemical characteristics of temperature abused coated mozzarella sticks

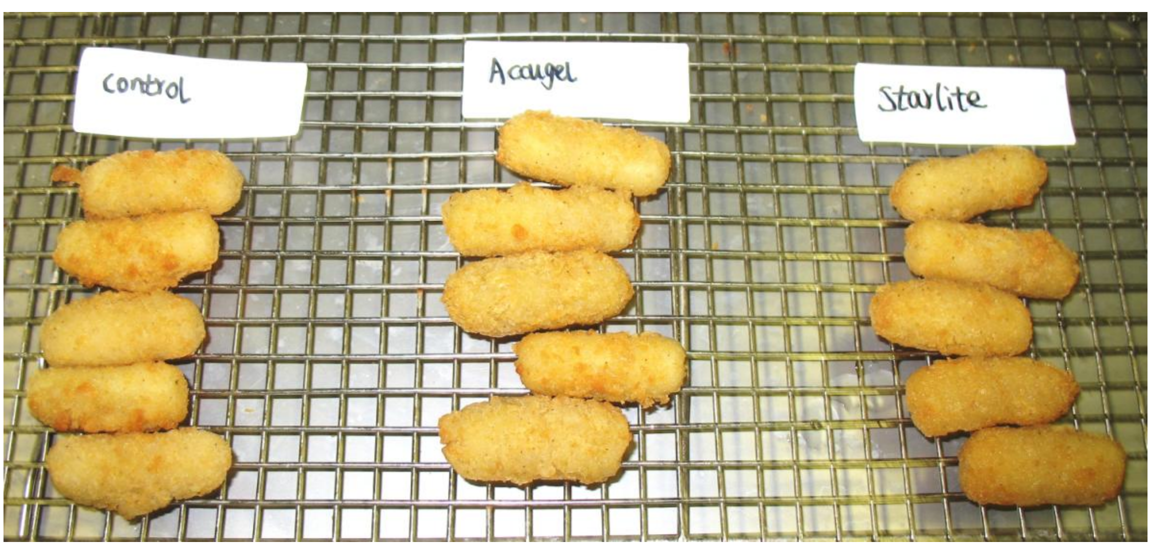
	Control[1]	Accu-Gel™[1]	Starlite™[1]	P-value
	Corn Starch	**Pea Starch**	**Pea Starch**	
Cook Yield, %	90.99[a]	93.33[b]	94.36[b]	0.001
Weight Loss[2] @ 30min, %	0.49	0.38	0.49	0.294
Weight Loss[2] @ 45min, %	0.68	0.56	0.77	0.254
Weight Loss[2] @ 60min, %	1.00	0.74	1.04	0.144
Moisture content[2], %	35.08	35.74	34.09	0.352

[1] Means represent quadruplicate observations
[2] Of fully fried mozzarella sticks
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

B. Sensory evaluation

At 5 minutes, the trained sensory panel rated coated mozzarella sticks made with pea starch (Accu-Gel™ or Starlite™) similarly to the control mozzarella sticks for all attributes; colour, crispness (moderately crispy), crunchiness (slightly to moderately crunchy), cheese texture (melted/soft) and overall quality (moderately to very high) (Table 31 & Figure 4). However at 5 minutes, significantly more beany flavour was noted for mozzarella sticks containing Starlite™ (slightly beany) compared to the control and Accu-Gel™ pea starch containing mozzarella sticks (no beany) but overall quality ratings were not affected.

Figure 4. A photograph comparing fully fried mozzarella sticks from starch replacement phase



At 45 minutes, colour and overall quality were not significantly different between the control and test samples but significant differences were noted for crispness, crunchiness, cheese texture, and beany flavour. After 45 minutes of holding, Starlite™ samples were rated significantly crunchier than Accu-Gel™ samples and significantly crisper than both Accu-Gel™ and the control mozzarella sticks. The higher level of crunchiness/crispness observed in Starlite™ over time could be related to its higher levels of protein and amylose. Altunakar et al (2004) noted that starches with high levels of amylose are good choices for use in a batter and breading application because amylose aids in the formation of a continuous membrane around the substrate which prevents moisture migration and allows the fried coating to become crisp. Starlite™ pea starch contains 5% more amylose than modified corn starch and 1% more amylose than Accu-Gel™ pea starch.

After 45 minutes, cheese texture of Starlite**™** containing samples was rated softer and beany flavour was rated higher than the control. Dry milled Starlite™ pea starch contains more protein (8%) versus the control (0.4%) which is likely responsible for the higher level of beany flavour. Proteins do not directly contribute much to flavour but they can bind flavour compounds in foods and release them through mastication of the food. Saponins (non-volatile flavour compounds) are known to contribute off-flavours in peas and tend to bind with proteins (Heng et al 2004).

Higher amylose levels in Starlite™ than Accu-Gel™ and the control may have formed a film around the cheese which as a result allowed the cheese to retain its moisture, thus making it softer. Cheese texture of Accu-Gel™ pea samples was also softer (not significantly) than the control most likely due to more amylose in Accu-Gel™ pea starch than corn starch. Despite Accu-Gel™'s higher amylose content, Accu-Gel**™** containing samples held 45 minutes were noted to have significantly less crunch than the control. Although, larger differences in crispness, crunchiness, and cheese texture were seen after 45 minutes between the test and control coated mozzarella sticks, the sensory panel's perception of overall quality remained moderately high for all samples.

Table 31 : Effect of pea starch on the sensory characteristics of coated mozzarella sticks

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	Pea Starch	Pea Starch	
Colour	5	1.78	1.56	1.67	0.636
0=white; 6=brown	45	1.89	1.78	2.00	0.557
Crispness	5	2.78	3.00	3.11	0.613
1=not crispy; 4=very crispy	45	2.33[a]	2.11[a]	3.11[b]	0.001
Crunchiness	5	2.67	2.22	2.56	0.389
1=not crunchy; 4=extremely crunchy	45	2.67[b]	2.11[a]	3.00[b]	0.001
Cheese Texture	5	3.11	3.33	3.11	0.404
1=very firm; 4=very soft	45	2.00[a]	2.44[ab]	2.56[b]	0.027
Beany Flavour	5	1.33[a]	1.11[a]	2.33[b]	0.000
1=none; 4=extreme	45	1.11[a]	1.33[ab]	2.11 [b]	0.007
Overall Quality	5	5.67	5.56	5.56	0.967
1=extremely low, 8=extremely high	45	4.67	4.56	4.78	0.915

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 10 person trained sensory panel
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Sensory characteristics of mozzarella sticks were not significantly affected by temperature abuse with the exception of beany flavour and cheese texture (Table 32). Starlite™ mozzarella sticks were rated more beany than control mozzarella sticks with 5 minutes hold time. At 45 minutes, both pea starch samples had softer cheese texture than the control which may be attributed to the higher level of amylose in pea starch versus corn starch. Overall quality of the three temperature abused samples was not affected by the differences in sensory attributes.

Table 32: Effect of pea starch on the sensory characteristics of temperature abused mozzarella sticks

	Time[1]	Control[2] Corn Starch	Accu-Gel™[2] Pea Starch	Starlite™[2] Pea Starch	P-value
Colour	5	1.50	1.33	1.42	0.728
0=white; 6=brown	45	1.58	1.33	1.58	0.389
Crispness	5	2.50	2.33	2.50	0.751
1=not crispy; 4=very crispy	45	1.92	1.75	2.25	0.205
Crunchiness	5	2.33	2.00	2.42	0.205
1=not crunchy; 4=extremely crunchy	45	1.92	2.08	2.08	0.586
Cheese Texture	5	3.33	3.75	3.17	0.052
1=very firm; 4=very soft	45	2.33[a]	2.92[b]	2.83[b]	0.009
Beany Flavour	5	1.25[a]	1.50[ab]	2.08[b]	0.019
1=none; 4=extreme	45	1.25	1.50	1.92	0.077
Overall Quality	5	5.75	5.42	4.58	0.093
1=extremely low, 8=extremely high	45	4.75	4.67	4.67	0.978

[1] Holding in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 10 person trained sensory panel
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

C. Objective results

The texture analyzer can potentially be used to identify tougher mozzarella stick coatings as perceived by sensory assessment. Based on sensory panellist ratings for the mozzarella sticks, the coating became less crispy/crunchy over time (except for Starlite™ sample) but instrumentally this was not observed (Table 33). At both 5 and 45 minutes, instrumental values for crispness/crunchiness and overall coating firmness were essentially unchanged for the control and test samples. However, samples containing Accu-Gel**™** were slightly less crunchy than the control and Starlite™. At 5 minutes, the sensory panel also rated Accu-Gel™ mozzarella sticks lower for crunchiness. At 5 and 45 minutes, both test samples had lower coating firmness values than the control but the differences were not significant.

Table 33: Effect of pea starch on the instrumental texture of mozzarella stick coatings

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	Pea Starch	Pea Starch	P < .05
Crispness/Crunchiness[3]	5 min	379.32	355.86	373.81	0.871
Overall Firmness[4]		7282.49	6342.16	5171.75	0.081
Crispness/Crunchiness[3]	45 min	403.74	348.21	409.48	0.419
Overall Firmness[4]		6858.76	6160.19	6777.40	0.431

[1] Holding (minutes) in a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent triplicate observations
[3] Crispness/Crunchiness determined by the initial gradient (slope); g/sec. Higher number = crispier/crunchier.
[4] Overall firmness determined by the area under the texture analysis curve, g*sec. Higher number = firmer.

After temperature abuse, no significant differences in instrumental texture were observed (Table 34) except for firmness; the control coating was significantly more firm than the Accu-Gel™ and Starlite™ coatings at 5 minutes which was also seen in properly handled (no temperature abuse) mozzarella sticks.

Table 34: Effect of pea starch on the instrumental texture of temperature abused mozzarella stick coatings

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	Pea Starch	Pea Starch	
Crispness/Crunchiness[3]	5 min	330.76	374.77	314.21	0.553
Overall Firmness[4]		7531.82[c]	6972.77[b]	5523.71[a]	0.041
Crispness/Crunchiness[3]	45 min	353.05	348.80	268.59	0.346
Overall Firmness[4]		7309.22	6811.72	5854.20	0.399

[1] Holding (minutes) in a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent triplicate observations
[3] Crispness/Crunchiness determined by the initial gradient (slope); g/sec. Higher number = crispier/crunchier.
[4] Overall firmness determined by the area under the texture analysis curve, g*sec. Higher number = firmer.
[a, b, c] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Coated mozzarella sticks containing pea starch were significantly brighter than control mozzarella sticks at 45 minutes before and after temperature abuse; at 5 minutes, temperature abused Starlite™ samples were significantly brighter than control samples (Table 35 & 36). Despite significant differences in colour, no consistent trends were seen in H and C values before or after 45 minutes holding of properly handled or temperature abused coated mozzarella sticks.

Table 35: Effect of pea starch on the instrumental colour of coated mozzarella sticks

	Time[1]	Control[2] Corn Starch	Accu-Gel™[2] Pea Starch	Starlite™[2] Pea Starch	P-value
L* (dark<light))	**5 min**	51.55	54.46	52.97	0.060
H (red<yellow)		76.71^{a}	81.53^{b}	78.54^{ab}	0.014
C (low<high)		28.06^{b}	22.53^{a}	23.80^{a}	0.000
L* (dark<light))	**45 min**	50.74^{a}	54.74^{b}	53.26^{b}	0.000
H (red<yellow)		77.59	79.47	78.88	0.108
C (low<high)		23.80^{ab}	24.72^{b}	22.02^{a}	0.010

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent 12 observations
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Table 36: Effect of pea starch on the instrumental colour of temperature abused coated mozzarella sticks

	Time[1]	Control[2] Corn Starch	Accu-Gel™[2] Pea Starch	Starlite™[2] Pea Starch	P-value
L* (dark<light)	**5 min**	50.37^{a}	53.73^{ab}	54.06^{b}	0.024
H (red<yellow)		79.78	81.31	80.83	0.700
C (low<high)		22.39	22.96	24.29	0.460
L* (dark<light)	**45 min**	46.65^{a}	53.04^{b}	55.11^{b}	0.000
H (red<yellow)		77.58	79.58	80.52	0.232
C (low<high)		16.39^{a}	21.38^{b}	22.38^{b}	0.003

[1] Holding (minutes) in a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent 12 observations
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Overall, both pea starches were similar in physiochemical and sensory properties and either would be suitable for this application. Wet milled Accu-Gel™ pea starch was chosen over Starlite™ for further optimization of the coated mozzarella stick because it had less effect on cheese texture and flavour of the fully fried product. However, dry milled Starlite™ pea starch also provided benefits, such as; increased crispy/crunchiness and increased moisture content of the final product.

3.6.2. Pea fraction optimization

Wet fractionated Accu-Gel™ pea starch was utilized to prepare two optimized pea coated mozzarella sticks: a pea/wheat crumb prototype and a GF pea prototype. Initially, a GF mozzarella stick was the aim but due to the lack of high quality, commercially available GF bread crumbs, a second prototype was also created using wheat containing bread crumbs. The two coated pea prototypes were compared against the same control mozzarella stick examined in the starch replacement phase. Pea ingredients tested in the coatings were starch, flour, hull fibre, and protein.

Three pea flours were initially evaluated for use in the mozzarella stick coatings; Best™ whole and split pea flours and Fiesta™ split pea flour. The WHC and the particle size of the pea flours were measured to better understand their functionality in the coating application (Chapter 2). Wheat and corn flours, guar gum, and wheat gluten in the three component coating system were replaced with pea flour as follows: in the pre-dust (soft wheat flour and wheat gluten), in the batter (all purpose and soft wheat flour, corn flour, and guar gum), and in the breader (soft and all purpose wheat flour).

All pea flours produced a smooth, runny batter but Best™ whole pea flour thickened a considerable amount upon standing. Mozzarella sticks made with Fiesta™ and Best™ split pea flour had more beany flavour and less golden colour compared to mozzarella sticks made with Best™ whole pea flour. Best™ whole pea flour (13.5%) also contains more fibre than Fiesta™ split pea flour (11.1%) and Best split pea flour (11%). Thus, Best™ whole pea flour was chosen for further optimization work due to less beany flavour, more golden colour, and a better nutritional profile.

Two dry fractioned pea hull fibres (Best™ and Exlite™) and one wet fractioned pea hull fibre (Centara™) were initially tested in mozzarella stick coatings. The WHC and the particle size distribution of each pea fibre is outlined in Table 15 (Chapter 2). To make a "source of fibre" nutrient content claim, a product must provide at least 2g of fibre per serving. Preliminary trials showed that addition of 4g of fibre to reach the "good source of fibre" claim produced an unacceptable product. Thus, the target for fibre addition was 2g per serving of mozzarella sticks and the usage level for each fiber was based on this. In the preliminary fiber trials, it was decided to group fiber and flour from the same supplier; however, wet milled pea flour does not exist, so wet milled Centara™ fiber was paired with Fiesta™ split pea flour. Best™ pea hull fibre was tested with Best™ whole pea flour and with Best™ split pea flour, while dry milled Exlite™ and wet milled

Centara™ fibres were studied with Fiesta™ split pea flour. Both Best™ and Exlite™ pea fibres resulted in a higher batter viscosity, darker coating colour, beanier flavour, and more mealy texture than Centara™ pea fibre. Thus, Centara™ pea fibre was chosen for use in the optimized mozzarella stick prototype.

Preliminary trials were conducted using pea protein isolate, Propulse™ in mozzarella stick coatings as a replacement for 25% of the flour in both the batter and the breader coating systems. Propulse™ caused the coatings to be more mealy and increased the ingredient cost for the mozzarella stick. Propulse™ also contributed a grassy flavour to the coating which was deemed unacceptable. Thus, no further testing with pea protein was conducted.

The most promising mozzarella sticks utilized a combination of pea starch, flour and hull fibre in the pre-dust, batter, and breader to fully replace corn starch/flour and wheat flour. Guar gum and wheat gluten from the test batter and pre-dust, respectively, were replaced with pea flour and fibre. Table 36 shows the pre-dust, batter, and breader formulas used for the preparation of pea containing mozzarella sticks. The GF pea prototype also utilized the formula shown in Table 37 except retail GF bread crumbs replaced commercial wheat based crumbs as follows: cracker meal in the pre-dust (ground Kinninnick), American bread crumbs in the breader (Glutino) and Japanese Panko style bread crumbs in the breader (Kinninnick).

Table 37: Optimized mozzarella stick coating containing pea ingredients and wheat bread crumbs

		Seasoning Formula	Dry Mix Formula	Hydrated Formula
PRE-DUST		%		
Base	Salt - hygrade	2.00	3.58	
	Black pepper, ground	0.30		
	Garlic powder	0.50		
	Onion powder	0.60		
	Celery seed, ground	0.10		
	Thyme, ground	0.08		
Cracker meal		----	70.27	
Pea flour - Best™ whole		----	12.00	
Pea fibre - Centara™		----	5.00	
Oil - vegetable, non hydrogenated		----	0.15	
Pea starch - Accu-Gel™		----	9.00	
Pre-dust Dry Mix Formula			**100.00**	
BATTER		**Seasoning Formula**	**Dry Mix Formula**	**Hydrated Formula**
		%		
Base	Salt - dendritic	4.00	7.50	2.5
	Sugar - fine, white, cane	2.50		
	Baking powder, SAPP*	1.00		
Pea flour - Best™ whole		----	67.50	22.5
Pea fibre - Centara™		----	5.00	1.67
Pea starch - Accu-Gel™		----	20.00	6.67
Batter Dry Mix Formula			**100.00**	
Water (4°C)				66.66
Hydrated Batter (2 parts water : 1 part dry mix)				**100.00**
BREADER		**Seasoning Formula**	**Dry Mix Formula**	
		%		
Base	Salt - dendritic	1.80	3.10	
	Celery seed, ground	0.06		
	Sage, ground	0.06		
	Marjoram, ground	0.06		
	Savory, ground	0.06		
	Garlic powder	0.21		
	Onion powder	0.42		
	Black pepper, ground	0.18		
	Oil - vegetable	0.21		
Pea flour - Best™ whole		----	42.00	
Bread crumb - American style		----	6.00	
Bread crumb - Japanese Panko style		----	40.00	
Pea fibre - Centara™			5.00	
Pea starch - Accu-Gel™		----	3.90	
Breader Dry Mix Formula			**100.00**	

*Sodium acid pyrophosphate

A. Physiochemical characteristics

Both optimized pea mozzarella stick prototypes were similar to the control for physiochemical attributes as no significant differences in batter viscosity, par fry yield, cook yield, or weight loss over time were observed (Table 38). However, the GF pea prototype had significantly more coating pick-up than the pea/wheat mozzarella stick; and cook yield was significantly higher than the control and the pea/wheat prototype. The pea/wheat prototype had similar coating pick-up and moisture content to the control but significantly higher total moisture than GF pea mozzarella sticks.

Table 38: Effect of pea ingredients and GF bread crumbs on the mean[1] physiochemical characteristics of coated mozzarella sticks

	Control[2]	Pea/Wheat[3]	GF Pea[4]	P-value
Batter Viscosity[5], centipoise	199.67	167.50	177.50	0.132
Coating Pick-up, %	62.87[ab]	62.45[a]	66.48[b]	0.022
Par fry Yield, %	102.35	102.82	101.56	0.084
Cook Yield, %	90.66[a]	90.92[a]	94.50[b]	0.052
Weight loss[6] @ 30min, %	0.61	0.47	0.58	0.238
Weight loss[6] @ 45min, %	1.00	0.74	0.99	0.116
Weight loss[6] @ 60min, %	1.40	1.07	1.37	0.146
Total Moisture[6], %	36.07[ab]	37.19[b]	35.31[a]	0.005

[1] Means represent quadruplicate observations
[2] Control made with all purpose and soft wheat flours & corn flour, guar gum, gluten & modified corn starches
[3] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre and wheat bread crumbs
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre and GF bread crumbs
[5] Measured with a Brookfield viscometer (Model RVDV-11 +PRO) with spindle 3 at 100RPM
[6] Of fully fried mozzarella sticks
[a, b] Means with differing superscripts are significantly different ($p<.05$) across rows

After temperature abuse, both pea prototypes had significantly higher cook yield versus the control and the pea/wheat mozzarella stick had significantly more total moisture than the control and the GF product (Table 39). The pea prototypes also had less weight loss over time than the control with significant differences between the GF prototype and control. This suggests that the pea prototypes retain moisture better and have less oil wicking than the control after freeze-thaw stress which could be attributed to higher amylose content of the pea ingredients. After temperature abuse, mozzarella sticks prepared with pea starch also had significantly higher cook yields than the control. Thus, pea starch may be beneficial for use in mozzarella stick coatings to increase moisture content, retain weight, and cook yield after temperature abuse.

Table 39: Effect of pea ingredients and GF bread crumbs on the mean[1] physiochemical characteristics of temperature abused coated mozzarella sticks

	Control[2]	Pea/Wheat[3]	GF Pea[4]	P-value
Cook Yield, %	94.09[a]	97.07[b]	98.02[b]	0.005
Weight loss @ 30min, %	1.16[b]	0.91[ab]	0.63[a]	0.004
Weight loss @ 45min, %	1.73[b]	1.41[ab]	1.01[a]	0.003
Weight loss @ 60min, %	2.35[b]	1.94[ab]	1.47[a]	0.004
Total Moisture, %	35.80[a]	37.69[b]	35.28[a]	0.000

[1] Means represent quadruplicate observations
[2] Control made with all purpose and soft wheat flours & corn flour, guar gum, gluten & modified corn starches
[3] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre and wheat bread crumbs
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre and GF bread crumbs
[5] Of fully fried mozzarella sticks
[a, b] Means with differing superscripts are significantly different (p<.05) across rows

B. Sensory evaluation

At 5 minutes hold time, both pea prototypes were significantly darker in colour and had significantly more beany flavour than the control (Table 40). No significant difference in crispness or cheese texture was perceived between mozzarella sticks at 5 minutes but the GF pea prototype was rated significantly less crunchy than control due to differences in bread crumb quality. At 5 minutes, both pea prototypes were rated significantly lower than the control for overall quality but all samples were rated in the acceptable range. Figure 5 shows visual differences between the control and pea containing mozzarella sticks (pea/wheat and GF).

For colour, crunchiness, and cheese texture at 45 minutes hold time, the same trends observed at 5 minutes also applied. At 45 minutes, the GF pea prototype was rated significantly less crispy and lower in overall quality than the pea/wheat prototype and the control. Also, significantly more beany flavour was detected in the GF pea mozzarella stick compared to the control. Thus, the GF pea prototype did not retain its quality when held under a heat lamp due to loss of crispness and an increase in beany flavour, whereas, the pea/wheat prototype and the control responded similarly to heat lamp conditions.

Table 40: Effect of pea ingredients and GF bread crumbs on the mean[2] sensory evaluation characteristics of coated mozzarella sticks

	Time[1]	Control[3]	Pea/Wheat[4]	GF Pea[5]	P-value
Colour	5	2.00[a]	3.25[b]	3.88[b]	0.000
0=light; 6=dark	45	2.00[a]	3.50[b]	4.25[b]	0.000
Crispness	5	3.50	2.75	2.50	0.054
1=not crispy; 4=very crispy	45	2.63[b]	2.38[b]	1.50[a]	0.001
Crunchiness	5	3.00[b]	2.38[ab]	2.00[a]	0.045
1=not crunchy; 4=extremely crunchy	45	2.38[b]	2.13[ab]	1.75[a]	0.036
Cheese Texture	5	3.50	3.50	3.63	0.863
1=very firm; 4=very soft	45	2.50	2.63	2.88	0.508
Beany Flavour	5	1.13[a]	2.13[b]	2.50[b]	0.004
1=none; 4=extreme	45	1.25[a]	2.13[ab]	2.63[b]	0.024
Overall Quality	5	6.00[b]	4.38[a]	4.13[a]	0.037
1=extremely low, 8=extremely high	45	5.50[b]	4.63[b]	3.50[a]	0.000

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 10 person trained sensory panel
[3] Control made with all purpose and soft wheat flours, guar gum, gluten, corn flour& modified corn starches
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[a, b] Means with differing superscripts are significantly different (p≤.05) across rows

Figure 5. A photograph comparing fully fried mozzarella sticks from pea ingredient optimization phase

Similar trends were observed in temperature abused mozzarella sticks as seen in properly handled mozzarella sticks (Table 41). After temperature abuse, the control and pea/wheat samples were rated slightly to moderately high for overall quality after 5 and 45 minutes holding, however, the GF pea prototype was rated below the border line for acceptance after 45 minutes in a food warmer. Thus, the quality of the GF pea prototype was compromised during handling abuse which highlights the importance and need for better quality GF bread crumbs.

Table 41: Effect of pea ingredients and GF bread crumbs on the mean[2] sensory evaluation characteristics of temperature abused coated mozzarella sticks

	Time[1]	Control[3]	Pea/Wheat[4]	GF Pea[5]	P-value
Colour	5	1.67[a]	3.78[b]	3.22[b]	0.000
0=light; 6=dark	45	1.44[a]	4.00[b]	3.89[b]	0.000
Crispness	5	2.67[b]	2.44[b]	1.44[a]	0.006
1=not crispy; 4=very crispy	45	2.00[b]	2.11[b]	1.00[a]	0.000
Crunchiness	5	2.33	2.22	1.78	0.093
1=not crunchy; 4=extremely crunchy	45	2.22[b]	1.89[ab]	1.56[a]	0.043
Cheese Texture	5	3.11	3.67	3.56	0.093
1=very firm; 4=very soft	45	3.00	3.22	3.44	0.079
Beany Flavour	5	1.33[a]	2.22[b]	3.22[c]	0.000
1=none; 4=extreme	45	1.22[a]	2.33[b]	2.78[b]	0.000
Overall Quality	5	5.00	4.22	3.67	0.086
1=extremely low, 8=extremely high	45	4.78[b]	4.33[b]	2.89[a]	0.018

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 10 person trained sensory panel
[3] Control made with all purpose and soft wheat flours, corn flour, guar gum, gluten, & modified corn starches
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[a, b, c] Means with differing superscripts are significantly different ($p \leq .05$) across rows

C. Objective results

Based on texture analysis values, all mozzarella stick coatings became less crispy/crunchy and less firm over time. The GF pea prototype was generally less crispy/crunchy and less firm than the control and pea/wheat prototype; sensory panellist ratings for crispiness/crunchiness confirmed this observation. However, texture analysis results at 5 and at 45 minutes revealed no significant differences between samples for crispness/crunchiness or overall firmness (Table 42). The standard deviations for texture of mozzarella stick coatings were quite high due to the inherent uneven texture of breaded coatings which may have skewed the results. A similar texture analysis issue was observed for breaded fish sticks in the earlier pea coatings study.

Table 42: Effect of pea ingredients and GF bread crumbs on the mean[2] instrumental texture of coated mozzarella sticks

	Time[1]	Control[3]	Pea/Wheat[4]	GF Pea[5]	P-value P ≤ .05
Crispness/Crunchiness[3]	**5 min**	424.24	341.86	101.39	0.565
Overall Firmness[4]		3330.53	3118.88	893.96	0.115
Crispness/Crunchiness[3]	**45 min**	90.73	102.81	48.64	0.458
Overall Firmness[4]		1585.45	1514.25	807.30	0.194

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent triplicate observations
[3] Control made with all purpose and soft wheat flours, corn flour, guar gum, gluten, & modified corn starches
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[6] Crispness/Crunchiness determined by the initial gradient (slope); g/sec. Higher number = crispier/crunchier.
[7] Overall firmness determined by the area under the texture analysis curve, g/sec. Higher number = firmer.

Again, no significant differences in instrumental texture were observed for temperature abused coated mozzarella stick prototypes (Table 43). It should be noted that the standard deviations for texture of the temperature abused mozzarella stick coatings were also quite high due to their inherent uneven breaded surface which may have affected the accuracy of the results.

Table 43: Effect of pea ingredients and GF bread crumbs on the mean[2] instrumental texture of temperature abused coated mozzarella sticks

	Time[1]	Control[3]	Pea/Wheat[4]	GF Pea[5]	P-value P ≤ .05
Crispness/Crunchiness[6]	**5 min**	113.24	97.36	66.12	0.148
Overall Firmness[7]		1612.00	1548.81	902.99	0.129
Crispness/Crunchiness[6]	**45 min**	69.84	41.83	58.97	0.262
Overall Firmness[7]		924.68	683.07	1093.39	0.296

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent triplicate observations
[3] Control made with all purpose and soft wheat flours, corn flour, guar gum, gluten & modified corn starches
[4] Made with Best whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Best whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[6] Crispness/Crunchiness determined by the initial gradient (slope); g/sec. Higher number = crispier/crunchier.
[7] Overall firmness determined by the area under the texture analysis curve, g/sec. Higher number = firmer

Differences for instrumental colour are shown in Table 44. At 5 minutes, there were no significant differences observed for brightness between the three samples but the pea/wheat prototype was significantly more red (lower hue value) than the control and the GF pea prototype and it had a higher C value than the GF pea mozzarella sticks. At 45 minutes, the pea/wheat mozzarella sticks were significantly less bright than the GF pea mozzarella stick and the control. Also at 45 minutes, both pea prototypes had significantly lower H and C values than the control. Protein creates more browning in fried mozzarella sticks by providing a higher number of amine groups to participate in the Maillard reaction (Mohamed et al 1998). Olewnik and Kulp (1990) also noted that flours with higher starch damage create darker coloured fried products. Pea flour contains more protein and starch damage than all purpose and soft wheat flours which may explain why pea containing mozzarella sticks were generally darker and redder than the control.

Table 44: Effect of pea fractions and GF bread crumbs on the instrumental colour of coated mozzarella sticks

	Time[1]	**Control[3]**	**Pea/Wheat[4]**	**GF Pea[5]**	**P-value**
L* (dark<light)	**5 min**	53.74	50.85	53.02	0.164
H (red<yellow)		75.55[b]	68.67[a]	73.24[b]	0.001
C (low<high)		22.69[ab]	24.40[b]	21.24[a]	0.022
L* (dark<light)	**45 min**	54.69[b]	51.17[a]	52.73[b]	0.002
H (red<yellow)		77.36[b]	69.52[a]	69.38[a]	0.005
C (low<high)		24.59[b]	22.14[a]	20.98[a]	0.001

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent quadruplicate observations
[3] Control made with all purpose and soft wheat flours, corn flour, guar gum, gluten, & modified corn starches
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Temperature abuse of the coated mozzarella sticks had minimal effect on product colour (Table 45). At 5 minutes, both temperature abused pea prototypes were less bright and redder than the control. At 45 minutes, the pea/wheat mozzarella stick was significantly less bright than the control and both pea prototypes were significantly redder than the control. After temperature abuse, C values were similar among the three mozzarella stick prototypes.

Table 45: Effect of pea fractions and GF bread crumbs on the instrumental colour of temperature abused coated mozzarella sticks

	Time[1]	Control[3]	Pea/Wheat[4]	GF Pea[5]	P-value
L* (dark<light)	**5 min**	56.28[b]	53.14[a]	52.48[a]	0.002
H (red<yellow)		82.60[b]	72.80[a]	69.98[a]	0.000
C (low<high)		18.43	17.79	16.91	0.324
L* (dark<light)	**45 min**	52.73[b]	50.70[a]	51.87[ab]	0.038
H (red<yellow)		75.77[b]	69.22[a]	67.27[a]	0.000
C (low<high)		17.68	17.99	17.44	0.763

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent quadruplicate observations
[3] Control made with all purpose and soft wheat flours, guar gum, gluten, corn flour& modified corn starches
[4] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Best™ whole pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[a, b] Means with differing superscripts are significantly different ($p \le .05$) across rows

3.7. Nutritional composition

Nutritional differences for par fried mozzarella sticks were observed when pea starch replaced corn starch. Mozzarella sticks with dry milled Starlite™ pea starch contained 0.5 to 1g more protein per 100g compared to corn starch and Accu-Gel™ mozzarella sticks. This was expected as Starlite™ pea starch contains more protein (8%) than corn starch (0.4%) and Accu-Gel™ pea starch (0.4%). Mozzarella sticks containing pea starch rather than corn starch provided 1.1 - 1.2g per 100g more total dietary fibre than the corn starch control. In addition, both pea starch mozzarella sticks had less sodium (22.1 - 38.5mg per 100g) than control mozzarella sticks. Thus by replacing corn starch with pea starch in this application, a mozzarella stick with higher fibre content and lower levels of sodium can be created with potential for higher protein depending on the selected pea starch. Table 46 shows the nutritional analysis results obtained from SGS Laboratories for the control (Phase 1 & 2), Accu-Gel™, Starlite™, optimized pea/wheat, and GF pea mozzarella sticks.

Table 46. Nutritional composition of par fried control and test mozzarella sticks per 100g[a]

		Control		Accu-Gel™	Starlite™	Pea/ Wheat	GF Pea
Phase		1	2	1	1	2	2
Energy	kcal	315.0	312.0	317.0	318.0	312.0	294.0
Protein (Nx6.25)	g	12.8	12.6	12.3	13.3	13.3	10.5
Fat	g	17.2	18.3	16.9	17.2	17.0	14.9
Calories from Fat	kcal	155.0	165.0	152.0	155.0	153.0	134.0
Saturated Fat	g	7.0	7.0	6.6	6.7	6.5	5.9
Monounsaturated Fat	g	7.6	8.4	7.6	7.7	7.8	6.8
Polyunsaturated Fat	g	2.6	2.7	2.7	2.8	2.5	2.0
Trans Fat	g	<0.1	0.2	<0.1	<0.1	0.2	0.2
Cholesterol	mg	29.0	25.0	25.0	27.0	26.0	33.0
Carbohydrates	g	27.3	24.2	28.9	27.6	26.5	29.4
Total Sugar	g	<0.1	4.1	<0.1	<0.1	1.1	1.5
Total Dietary Fibre	g	2.5	1.9	3.6	3.7	5.5	5.5
Insoluble Fibre	g	---	1.4	---	---	5.2	5.0
Soluble Fibre	g	---	0.5	---	---	0.3	0.5
Sodium	mg	625.5	634.8	587.0	603.4	641.1	814.7
Calcium	mg		215.3			239.4	270.2
Iron	mg		1.5			1.9	1.4
Moisture	g	40.4	42.6	39.8	39.6	40.8	42.0
Ash	g	2.3	2.3	2.1	2.3	2.4	3.2
Vitamin A	IU		32.0			14.5	11.3
Vitamin C	mg		<1			<1	<1

[a] Results were obtained from SGS Laboratories (Vancouver, BC)

When the coating formulation was optimized to replace corn starch plus other traditional ingredients (corn and wheat flours, guar gum, and gluten) with pea ingredients, greater nutritional differences were observed among par fried samples (Table 46). Overall, test mozzarella sticks contained 3.6g per 100g more dietary fibre (insoluble form) than the control because pea ingredients (flour and fibre) contribute more fibre than the traditional ingredients they replaced. The optimized pea/wheat prototype also contained 0.7g per 100g more protein than the control but the protein content of the GF pea prototype was 2.1g less per 100g versus the control. The higher level of protein in the optimized pea/wheat prototype was due to the high protein content of pea flour.

The GF pea prototype had lower protein (2.1-2.8g per 100g less), lower fat (2.1–3.4g per 100g less), higher sodium (174-180mg per 100g more), and higher calcium (30.8 – 54.9mg per 100g more) than the control and pea/wheat mozzarella sticks partially due to the nutritional composition of the GF bread crumbs. The GF pea prototype also had a higher coating pick-up and thus less of the cheese (high in fat) and more coating than the control and the optimized pea/wheat product. Thus, the overall fat content of the GF mozzarella stick was reduced because the coating contains less fat than the cheese.

Thus, replacing traditional coating ingredients with pea ingredients can result in a breaded mozzarella stick with higher levels of fibre and with potentially more protein or less fat depending on the type of bread crumbs selected and substrate used. When replacing only starch in the coating, slight sodium reductions are also possible with pea starch use.

Nutritional analysis of par fried mozzarella sticks was also conducted after two freeze-thaw cycles to determine if temperature abuse had an effect on the nutritional profile. Results are not shown because no notable differences were observed between par fried mozzarella sticks after temperature abuse.

According to the Canadian Guide to Food Labeling and Advertising (Schedule M, Table 6.1), the reference amount for mozzarella sticks (hors d'oeuvres) is 50g and the serving size can range from 25 - 100g. Nutritional facts panels for mozzarella sticks containing either corn starch (control), Accu-Gel™ pea starch or Starlite™ pea starch, and for the optimized pea/wheat prototype and the GF pea prototype are shown in Figure 6.

Figure 6: Nutritional facts panels for control and test samples of breaded, par fried mozzarella sticks

Breaded Mozzarella Sticks – Control
(Modified corn starches)

Nutrition Facts	
Valeur nutritive	
Per (50 g) / par (50 g)	
Amount **Teneur**	**% Daily Value** **% valeur quotidienne**
Calories / Calories 160	
Fat / Lipides 9 g	**14** %
Saturated / saturés 3.5 g + Trans / trans 0.1 g	**18** %
Cholesterol / Cholestérol 15 mg	
Sodium / Sodium 320 mg	**13** %
Carbohydrate / Glucides 12 g	**4** %
Fibre / Fibres 1 g	**4** %
Sugars / Sucres 2 g	
Protein / Protéines 6 g	
Vitamin A / Vitamine A	6 %
Vitamin C / Vitamine C	-- %
Calcium / Calcium	10 %
Iron / Fer	6 %

Breaded Mozzarella Sticks
(Accu-gel™ pea starch)

Nutrition Facts	
Valeur nutritive	
Per (50 g) / par (50 g)	
Amount **Teneur**	**% Daily Value** **% valeur quotidienne**
Calories / Calories 160	
Fat / Lipides 8 g	**12** %
Saturated / saturés 3.5 g + Trans / trans 0 g	**18** %
Cholesterol / Cholestérol 15 mg	
Sodium / Sodium 290 mg	**12** %
Carbohydrate / Glucides 14 g	**5** %
Fibre / Fibres 2 g	**8** %
Sugars / Sucres 0 g	
Protein / Protéines 6 g	
Vitamin A / Vitamine A	-- %
Vitamin C / Vitamine C	-- %
Calcium / Calcium	-- %
Iron / Fer	-- %

Breaded Mozzarella Sticks
(Starlite™ pea starch)

Nutrition Facts	
Valeur nutritive	
Per (50 g) / par (50 g)	
Amount **Teneur**	**% Daily Value** **% valeur quotidienne**
Calories / Calories 160	
Fat / Lipides 9 g	**14** %
Saturated / saturés 3.5 g + Trans / trans 0 g	**18** %
Cholesterol / Cholestérol 15 mg	
Sodium / Sodium 300 mg	**13** %
Carbohydrate / Glucides 14 g	**5** %
Fibre / Fibres 2 g	**8** %
Sugars / Sucres 0 g	
Protein / Protéines 7 g	
Vitamin A / Vitamine A	-- %
Vitamin C / Vitamine C	-- %
Calcium / Calcium	-- %
Iron / Fer	-- %

Optimized Pea/Wheat Breaded Mozzarella Sticks
(Accu-gel™ pea starch, Best™ whole pea flour & Centara™ pea fibre)

Nutrition Facts	
Valeur nutritive	
Per (50 g) / par (50 g)	
Amount **Teneur**	**% Daily Value** **% valeur quotidienne**
Calories / Calories 160	
Fat / Lipides 9 g	**14** %
Saturated / saturés 3.5 g + Trans / trans 0.1 g	**18** %
Cholesterol / Cholestérol 15 mg	
Sodium / Sodium 320 mg	**13** %
Carbohydrate / Glucides 13 g	**4** %
Fibre / Fibres 3 g	**12** %
Sugars / Sucres 1 g	
Protein / Protéines 7 g	
Vitamin A / Vitamine A	2 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	10 %
Iron / Fer	6 %

Gluten-Free Pea Breaded Mozzarella Sticks
(Accu-gel™ pea starch, Best™ whole pea flour & Centara™ pea fibre)

Nutrition Facts	
Valeur nutritive	
Per (50 g) / par (50 g)	
Amount **Teneur**	**% Daily Value** **% valeur quotidienne**
Calories / Calories 150	
Fat / Lipides 7 g	**11** %
Saturated / saturés 3 g + Trans / trans 0.1 g	**16** %
Cholesterol / Cholestérol 15 mg	
Sodium / Sodium 410 mg	**17** %
Carbohydrate / Glucides 15 g	**5** %
Fibre / Fibres 3 g	**12** %
Sugars / Sucres 1 g	
Protein / Protéines 5 g	
Vitamin A / Vitamine A	2 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	10 %
Iron / Fer	6 %

Thus through the addition of pea ingredients, a "source of fibre" claim can be made on the mozzarella sticks as they contain 2-3g of fibre per 50g serving. Control mozzarella sticks did not meet the requirements for a fibre claim as they only provided 1g of fibre per 50g serving.

3.8. Cost implications

Table 47 shows prices for pea ingredients as well as traditional coating ingredients. Pea starch was estimated to cost an additional $0.11-0.13 CDN /lb over corn starch. Pea flour was priced similarly to wheat flour and slightly less than corn flour. Guar gum and wheat gluten, two expensive ingredients, were also removed from the formula and replaced with pea flour and pea fibre which are less expensive.

Table 47: Coating ingredient price comparison (excluding crumb)

Ingredient	CDN $/lb
Wheat Flour – soft*	$0.41
Wheat Flour – all purpose*	$0.43
Corn Flour – yellow*	$0.50
Pea Flour**	$0.40
Modified Corn Starch*	$0.82
Instant Corn Starch*	$0.84
Native Pea Starch**	$0.95
Guar Gum*	$4.00
Wheat Gluten*	$1.20
Pea Fibre**	$0.62

* Commodity price estimates per national vendors, March 2012
** Average price based on Canadian pea fraction suppliers, January 2012

Table 48 shows the estimated cost of ingredients for the control, the pea starch prototype, and the optimized pea/wheat mozzarella stick. Based on ingredient cost per pound of hydrated coating, the pea starch mozzarella stick was $0.02 to 0.03 CDN /lb more than the control, whereas, the optimized pea/wheat prototype was $0.02 CDN /lb less due to the removal of guar gum and wheat gluten. Thus utilization of pea ingredients like pea flour, pea fibre, and pea starch in coatings has the potential to slightly decrease food manufacturers' ingredient costs while maintaining sensory quality and improving the nutritional profile of the mozzarella sticks.

Table 48: Coating dry mix cost comparison (CDN /lb) excluding crumb

	Control[1]	Pea Starch[2]	Optimized Pea/Wheat[3]
Starch	Corn	Pea	Pea
Flour	Wheat/Corn	Wheat/Corn	Pea
Fibre	--	--	Pea
Gluten & gum	Gluten/Gum	Gluten/Gum	--
Pre-dust	$0.191	$0.203	$0.165
Hydrated Batter (2 parts water: 1 part dry)	$0.165	$0.174	$0.164
Breader	$0.228	$0.232	$0.236
Price difference from control	**$0.000**	**$0.025**	**-$0.019**

[1] Control made with all purpose & soft wheat flours, corn flour, gluten, guar gum & modified corn starches
[2] Modified corn starch was fully replaced by pea starch
[3] Made with Best™ whole pea flour, Accu-Gel™ pea starch, Centara™ pea fibre & wheat bread crumbs

3.9. Conclusions – Mozzarella sticks

Mozzarella stick coatings containing pea starches (Accu-Gel™ or Starlite™) as 100% replacement for cook-up and instant corn starch generally performed at an acceptable level compared to the control. Native pea starch increased batter viscosity ($p \leq 0.05$) compared to batters containing modified cook-up corn starch because of its larger granule size, more starch damage, and higher amylose levels but batter containing pea starch was still process capable. No differences in par fry yield, cook yield, coating pick-up, or weight loss with heat lamp exposure were observed in coated mozzarella sticks containing pea or corn starch. Moisture content of fully fried mozzarella sticks with Starlite™ pea starch was significantly higher than that of Accu-Gel™ and control prototypes. The moisture retention during frying may be attributed to its higher protein and amylose content which enabled formation of a film around the cheese to inhibit the loss. After temperature abuse, cook yield of both fully fried pea starch mozzarella sticks was significantly higher than that of the control, which was likely due to better coating strength resulting from high amylose levels in pea starch.

At 5 minutes holding, mozzarella sticks made with pea starch (Accu-Gel™ or Starlite**™**) in the coating were similar to the control mozzarella sticks for the following sensory characteristics: overall quality (very high), colour, crispness (slightly to moderately crispy), and crunchiness (slightly to moderately crunchy). Sensory panellists' ratings showed that mozzarella sticks made with Starlite™ pea starch had significantly more beany flavour and more crispness than Accu-Gel™ containing prototypes and the control. After 45 minutes of holding under a heat lamp, both pea starch mozzarella sticks had softer cheese texture than the control which was an effect also observed in physiochemical observations.

Both cook-up and instant corn starches were successfully replaced with native pea starch as evidenced by physiochemical and sensory results. The nutritional profile of the pea starch mozzarella stick was slightly improved and the ingredient label cleaner with the replacement of modified corn starches by native pea starch. The cost to replace corn starch with pea starch is $0.02 – 0.03 CDN/lb dry mix more as pea starch is currently more expensive than corn starch.

Combining pea starch with pea flour and pea hull fibre to replace traditional coating ingredients resulted in an acceptable coating system for mozzarella sticks. Use of pea starch with pea flour successfully replaced guar gum and wheat gluten in the coating formula resulting in a cleaner label and a less expensive coating compared to the control.

Pea protein isolate in the coating did not improve sensory quality of the coated mozzarella sticks. Total replacement of wheat and corn flours, corn starch, guar gum, and wheat gluten with pea ingredients produced a prototype that was very similar in quality to the control.

GF bread crumbs replaced wheat bread crumbs to produce GF mozzarella sticks but the resulting GF product had lesser quality than the mozzarella sticks containing wheat crumbs as per sensory results.

The optimized pea/wheat mozzarella stick had similar batter viscosity, par fry yield, and cook yield to the control and GF pea prototype. Compared to the control, the pea/wheat prototype had similar coating pick-up and moisture content and after temperature abuse, it had higher moisture content and a higher cook yield.

The optimized pea/wheat prototype was significantly more golden with softer cheese (at 5 minutes) and more beany flavour than the control but no differences in coating texture or overall quality were noted by sensory panellists. Differences in colour, cheese texture, and flavour did not affect overall quality as the pea/wheat and control mozzarella sticks were rated similarly.

The par fried optimized pea/wheat mozzarella sticks contained more protein and dietary fibre (insoluble) than the control which can be attributed to increased levels of protein and fibre contributed by pea flour and pea fibre versus traditional ingredients. A "source of fibre" claim can be made for both pea starch mozzarella sticks and for the optimized pea/wheat product, whereas, the control mozzarella sticks does not meet the requirements to make a fibre claim.

By utilizing pea ingredients (native starch, flour, and hull fibre) to replace traditional ingredients in the coatings of mozzarella sticks, a cost savings of $0.02 CDN/lb of coating and a cleaner label was obtained.

3.10. Opportunities & challenges – Mozzarella sticks

Opportunities and challenges associated with utilizing pea ingredients in a six step breading application for mozzarella sticks or similar food products.

Opportunities for pea ingredients:

1) Cheese texture: pea starch can be used to produce a cheese texture that remains softer (more melted) after frying.

2) Moisture retention: a combination of pea starch, pea flour, and pea hull fibre can provide better moisture retention in fully fried products even after temperature abuse; if pea starch is used without pea flour and pea hull fibre, dry milled pea starch exhibits a greater effect than wet milled pea starch.

3) Improved texture: dry milled pea starch can increase crispness of fried products held under a heat lamp.

4) Cook yield: pea starch and a combination of pea starch, flour and hull fibre improve cook yield of product after temperature abuse.

5) Fibre claim: 'source of fibre' claim can be made by adding pea starch alone or in combination with pea flour and pea hull fibre.

6) Gluten-free: pea starch, flour, and hull fibre can be used in combination with GF bread crumbs to develop GF breaded products.

7) Batter viscosity: pea starch, pea flour, and pea fibre can all increase batter viscosity so functional ingredients (gum and gluten) can be replaced. Greater batter viscosity can be obtained with whole pea flour and with dry milled pea hull fibre.

8) Enhanced colour: pea flour contributes a golden colour to fried products so it can replace corn flour and wheat gluten.

9) Ingredient cost reduction: a combination of pea starch, pea flour, and pea hull fibre can replace more expensive ingredients (wheat and corn flours, guar gum, wheat gluten) and offset the slightly higher price for pea starch for an overall cost savings. Additional cost reductions may be possible for pea starch batters by optimizing batter hydration.

10) Cleaner label: pea flour and hull fibre can replace functional ingredients (guar gum and wheat gluten) and native pea starch can replace modified corn starch, thus, creating a shorter, more 'green' ingredient listing.

11) Improved nutritional profile: pea starch can increase fibre and protein and also decrease sodium of par fried products and when combined with pea flour and fibre, the fibre content can be further increased. High protein levels can be obtained with dry milled pea starch.

Challenges for pea ingredients:

1) Batter viscosity: pea starch, pea flour, and pea hull fibre all provide increased batter viscosity but process capable batters can be produced.

2) Off Flavour: dry milled pea starch and pea flour both contributed a beany flavour but pea starch use does not impact overall quality. Whole pea flour contributes less beany flavour than split pea flour but acceptable products can be produced from both.

4.0. ONION RINGS

4.1. Experimental Design

The onion ring portion of the study was split into two phases; (1) starch replacement and (2) optimized replacement of starch, flour, gluten, whey, and guar gum with pea ingredients. Two optimized onion ring prototypes were produced: (1) a pea prototype with wheat crumbs and (2) a GF version containing GF crumbs. Two optimized pea prototypes were prepared to assess the use of pea ingredients in GF onion rings.

In the starch replacement phase, both dry milled Starlite™ and wet milled Accu-Gel™ pea starches were tested. A three step coating system (pre-dust, batter, breader) was used. In the control onion ring coating system, the pre-dust contained both cook-up and instant starches, the batter contained cook-up starch, and the breader did not contain starch. Full replacement of corn starches (cook-up and instant) with pea starch was tested.

In the optimization phase, the most successful pea starch from the starch replacement phase was used in combination with other pea ingredients to develop both a pea/wheat and a GF pea onion ring. Three pea flours, three pea hull fibres, and one pea protein isolate were evaluated in the onion ring coating as replacements for corn starch, wheat flour, corn flour, soy flour, wheat gluten, whey, and guar gum. The retail GF bread crumbs (American and Japanese Panko style) and cracker meal used in the mozzarella sticks were also used in the onion ring application. The pea fractions evaluated in the onion ring coatings, pea ingredient suppliers, and the fractionation method are provided in Chapter 2 (Table 1).

4.2. Materials

4.2.1. Onions

Fresh, yellow, sliced (½" thick) onions were supplied by Gills Onions (Oxnard, CA) and stored at 4°C in vacuum sealed packages at FDC until required for trials. The nutrition facts table for the sliced onions is shown in Figure 8.

Figure 8: Nutrition facts table for yellow, sliced onions

Nutrition Facts Valeur nutritive Per (100 g) / par (100 g)	
Amount Teneur	**% Daily Value % valeur quotidienne**
Calories / Calories 40	
Fat / Lipides 0.1 g	**1** %
Saturated / saturés 0 g + Trans / trans 0 g	**0** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 4 mg	**1** %
Carbohydrate / Glucides 9 g	**3** %
Fibre / Fibres 2 g	**8** %
Sugars / Sucres 4 g	
Protein / Protéines 1 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	10 %
Calcium / Calcium	2 %
Iron / Fer	2 %

4.2.2. Coating system

Commercial onion ring coating dry mixes were supplied by Newly Weds Foods (Mississauga, ON). The control coating formula for the pre-dust, batter, and breader are shown in Table 49. Coating mixes were blended using a Hobart food mixer with a wire whisk attachment to ensure uniformity. Viscosity of the hydrated batter was measured using a Stein Cup (seconds of flow from full to empty) to mimic methods used in industry, as well as with a Brookfield viscometer (Model RVDV-11 +PRO) with spindle 4 at 100RPM for 15 seconds for better accuracy.

Table 49. Control pre-dust, batter, and breader formulas for onion ring coatings

PRE-DUST			Dry Mix Formula	
			%	
Cracker meal			64.00	
Flour - wheat, all purpose, unbleached			10.00	
Wheat gluten			5.00	
Starch - cook-up, corn, modified			15.00	
Starch - instant, corn, modified			3.00	
Oil - vegetable, non-hydrogenated			0.50	
Salt - hygrade			2.50	
PRE-DUST Dry Mix Formula			**100.00**	
BATTER			**Dry Mix Formula**	**Hydrated Formula**
			%	%
Flour - corn			15.00	5.77
Flour - wheat, all purpose, unbleached			47.75	18.36
Flour - wheat, soft, unbleached			25.00	9.62
Flour - soy			1.50	0.58
Whey			0.30	0.12
Starch - cook-up, corn, modified			3.00	1.15
Gum - guar			0.25	0.09
Baking powder - SAPP*			1.20	0.46
Sugar			1.50	0.58
Oil - vegetable, non-hydrogenated			1.00	0.38
Salt - hygrade			3.50	1.35
BATTER Dry Mix Formula			**100.00**	
Water (4°C)				61.54
Hydrated Batter (1.6 parts water : 1 part dry mix)				**100.00**
BREADER		**Seasoning Blend**	**Dry Mix Formula**	
		%	%	
Base	Salt, hygrade	2.00	4.50	
	Garlic powder	0.50		
	Onion powder	0.80		
	Marjoram, ground	0.01		
	Cheese, romano	0.50		
	Parsley flakes	0.20		
	Basil, rubbed	0.15		
	Oregano, rubbed	0.15		
	Pepper, black, 35/70	0.20		
Flour - wheat, all purpose, bleached			25.00	
Bread crumb - American style			10.00	
Bread crumb - Japanese Panko style			60.00	
Oil - vegetable, non-hydrogenated			0.50	
BREADER Dry Mix Formula			**100.00**	

*Sodium acid pyrophosphate

4.3. Sample preparation

The refrigerated onions were soaked in hot water (45 – 55°C) for 10 – 12 minutes. The onions were drained, the rings were separated, and the thin inner membrane was manually removed. Industry recommends soaking onions to reduce pungent onion aroma and flavour and to facilitate easy removal of the thin inner membrane. Pre-dust and breader coating dry mixes were spread onto parchment lined trays. Cold water (4°C) was added to the batter and mixed with an electric mixer (Sunbeam Mixmaster) for one minute at medium speed and the batter was held for 10 minutes over ice to fully hydrate. The peeled, separated onion rings were manually covered in pre-dust and tapped three times on the side of the tray to remove excess pre-dust. Then, the pre-dusted onion ring was submerged in the batter for five seconds and held on a fork for an additional five seconds to remove excess batter. The battered onion rings were manually covered in breader; then the coated onion rings were par fried (Garland Deep Fryer, SF) at 199°C (390°F) for 25 seconds using non-hydrogenated canola oil (Canola Harvest). Coating pick-up was measured in duplicate using two onion rings as a sample and batch weights were taken to calculate total batch pick-up.

$$\text{Coating Pick-up (\%)} = \frac{\text{(coated weight – initial weight)}}{\text{coated weight}} \times 100$$

The capacity of the fryer was 18L. To maintain oil quality, 6L of used oil was blended with 12L of fresh oil after frying eight batches. Par fried onion rings were held in the frying basket for one minute to drain excess oil; then they were transferred to a parchment lined sheet pan and frozen overnight at -18°C (O°F). Onion rings were then bagged and stored frozen (-18°C) for a minimum of 14 days. Four batches of each treatment were prepared to minimize processing effects and to generate a larger number of ‘batch’ observations. Par fried weights were taken and par fry yield was calculated based on raw batch weight.

$$\text{Par Fry Yield (\%)} = \frac{\text{par fry batch weight}}{\text{raw batch weight}} \times 100$$

An equal portion from each of the four production replicates were blended together to create a pooled sample for each treatment. For sensory and analytical testing, onion rings were fully fried at 177°C (350°F) for two minutes using non-hydrogenated canola oil (Canola Harvest). Cooked weights were taken and cook yield was calculated based on frozen par fried batch weight.

$$\text{Cook yield (\%)} = \frac{\text{cooked batch weight}}{\text{frozen batch weight}} \times 100$$

4.4. Test methods

4.4.1. Sensory evaluation

Sensory evaluation by a 10 person trained panel was used to quantify the intensities of five attributes. Category scales were used (4 points) for the following attributes: crispness, crunchiness/hardness, beany flavour, and overall quality (Appendix G). Colour was assessed using the Newly Weds Flour Breader Fry Colour Chart (6 points) (Appendix F). Onion rings were placed under a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs and evaluated at 5 and 50 minutes after frying. Current food service practices dictated the hold time of 50 minutes. Samples were presented in random order and labelled with random three-digit codes. The variability between onion rings was minimized by cutting each onion ring into three pieces and serving two pieces from the pooled sample. Panellists were given room temperature distilled water and unsalted crackers to cleanse their palate between samples. Three samples per session were evaluated to minimize panellist fatigue.

4.4.2. Nutritional analysis

SGS Canada Inc. (Vancouver, BC) analyzed the frozen par fried onion rings and provided results for the following: energy, protein, fat, calories from fat, saturated fat, monounsaturated fat, polyunsaturated fat, trans fat, cholesterol, carbohydrates, total sugar, total dietary fibre, insoluble fibre, soluble fibre, sodium, calcium, iron, moisture, ash, vitamin A, and vitamin E. Proximate analysis was also conducted on temperature abused onion rings to determine any effect on nutritional composition. All methods used in the analysis of the nutritional components were in compliance with AOAC approved methods and Health Canada regulations.

4.4.3. Weight loss

Weight loss over time was determined by testing two randomly selected fully fried onion rings from each treatment. Each onion ring was placed on a pre-weighed Whatman 1 filter paper (1.5mm thick). The initial weight of the onion rings was recorded. Filter papers with onion rings were placed (minimum of 12mm spacing) beneath the food warmer (OHC-500 Heat Lamp; positioned at maximum height of 60cm above sample) and held for 60 minutes. Onion rings were weighed at set time intervals; 30, 45, and 60 minutes.

$$\text{Weight loss (\%) after “x” minutes} = \frac{\text{(cook weight – weight @ “x” min)}}{\text{cook weight}} \times 100$$

4.4.4. Moisture content

Moisture content of fully fried onion rings was determined using a modified AOAC Method 925.10. Fully cooked onion rings were cooled for 2 minutes and placed in a plastic freezer bag and stored in the freezer. The next day, the frozen onion rings were ground in a coffee grinder on espresso setting for one minute. A 2-3g sample was transferred to a small metal pan and dried at 70°C for 24 hours in a conventional moisture oven (Cole Parmer), then placed in a desiccator to cool. The formula below was used to calculate the total moisture.

$$\text{Total Moisture \%} = \frac{\text{frozen cook weight – dried weight}}{\text{frozen cook weight}} \times 100$$

4.4.5. Instrumental texture

Texture analysis to determine the crispness/crunchiness and overall firmness over time was conducted in triplicate on fully fried onion rings using a Texture Analyzer TA-X2i with the TA-42 Knife probe (45° chisel blade) attached. This cut test was designed to imitate incisor teeth cutting through the fried coating of an onion ring. The total energy (area under the curve; g/sec) indicates overall firmness, whereas, the initial slope (g/sec) is an indicator of crispness/crunchiness. Texture analysis was used to strengthen sensory results for crispness and crunchiness. Texture was measured at both 5 and 50 minutes using a $1cm^2$ piece of coating. The texture analyzer was equipped with a 25kg load cell and a guillotine holder so that the knife would contact the midpoint of the coating and fully cut through. The texture analyzer was set at a test distance of 9mm, a pre-test crosshead speed of 2mm/sec until 5g of resistance was sensed, a test crosshead speed of 1mm/sec, and a post-test speed of 2mm/sec. Each onion ring was cut open lengthwise and the onion was removed leaving the coating intact. The coating was then trimmed to a $1cm^2$ portion. Appendix D shows a typical curve that is generated by the texture analyzer and highlights where firmness and crispness/crunchiness values are taken from.

4.4.6. Instrumental colour

Coating colour measurements from each treatment were taken on four randomly selected onion rings from each treatment after 5 and 50 minutes of exposure to the food warmer. Three measurements from random locations on the surface were taken per ring; two from one side and one from the opposite side. The Konica Minolta chroma meter (Model CR-400) was used to determine L*a*b* values using an 8mm aperture. The chroma meter was calibrated with a white tile prior to testing (No. 18733148: CIE L* 97.63, a* -0.01, b* 1.60). L_0, a_0, and b_0 represent the colour parameters of the onion ring at 5 minutes of holding (referred to as a standard reference), whereas, L*, a*, and b* are the corresponding colour parameters from onion rings that have been temperature abused or held 50 minutes under the food warmer. L* represents brightness of onion ring coating. H and C difference values were calculated from a* and b* results to aid in relating instrumental results to visual assessment. To calculate the H and C values, the calculations below were used.

$$\text{Hue angle difference (H)} = \tan^{-1}(b^*/a^*) - \tan^{-1}(b_0/a_0)$$

$$\text{Chroma difference (C)} = [(a^*-a_0)^2 + (b^*-b_0)^2]^{0.5}$$

The lower the H angle, the redder the onion ring coating, while the higher the H angle, the more yellow the coating. C is a measure of the colour intensity of the onion ring coating after fully frying where higher values indicate greater colour intensity. The lower the L* value, the darker the coating while the higher the L* value, the brighter the coating.

4.4.7. Freeze-thaw stability

Par fried onion rings were temperature abused through two freeze-thaw cycles. Samples were removed from the storage freezer (-18°C), placed on parchment lined sheet pans, covered with cellophane wrap, and then held at room temperature. Samples were tempered to a surface temperature of 4°C then blast frozen for 20 minutes at -40°C to a surface temperature of -25°C. Onion rings were then stored overnight in a walk-in storage freezer at -18°C. The tempering and blast freezing process was repeated and samples were repackaged and stored in the freezer at -18°C for a minimum of 14 days. Temperature abused onion rings were fried as per methods described previously and evaluated by the trained panel (n=10) after 5 and 50 minutes of holding under a heat lamp.

4.5. Statistical analysis

Statistical analysis of variance (ANOVA) was carried out using Predictive Analytics SoftWare 12.0.1 for Windows (IBM Corporation, Somers, NY). Significance of treatment means were determined (α = 0.05 level of significance) with Tukey or Scheffe, depending on equality of sample size.

4.6. Results & discussion

4.6.1. Starch replacement

A. Physiochemical characteristics

Based on results from the mozzarella stick application, it was hypothesized that cook-up and instant modified corn starch found in traditional onion ring coatings could be fully replaced with native pea starch. Thus, the performance of native pea starch as a 100% replacement for both cook-up and instant modified corn starch in a commercial onion ring coating was evaluated.

Both wet and dry milled pea starches were tested in the onion ring application. The milling process (dry or wet) affects starch purity and the degree of starch damage which can impact batter viscosity. Dry milling is generally known to produce a less pure starch with more starch damage; however, it is a more economical process.

Key production indicators for commercial coating systems include batter viscosity, coating pick-up, and cook yields. Control batters containing cook-up corn starch ranged from 22-25 seconds, batters containing Accu-Gel™ ranged from 24-26 seconds, and batters containing Starlite™ ranged from 23-25 seconds according to the Stein Cup method. Thus, pea starch had a minimal effect on batter viscosity and all batters were process capable as expected due to the small percentage of starch in the batter (3%). No significant differences in batter viscosity (Brookfield viscometer) between batters with different starch types or milling methods were observed (Table 50).

Control and Accu-Gel™ pea starch onion rings had significantly higher coating pick-up than those containing Starlite™ pea starch. As expected, onions rings with more coating pick-up had higher par fry yields. All onion rings tested had significantly different par fry yields; Accu-Gel™ onion rings had the highest par fry yield, followed by the control and then Starlite™ onion rings. Despite significantly higher par fry yield for Accu-Gel™ and control onion rings compared to Starlite™, no significant difference in cook yield was observed. The cook yield weights between starch prototypes may have evened out after fully frying due to better coating adhesion provided by Starlite™ (higher protein) in the pre-dust.

Moisture retention in coating systems is a primary concern when replacing modified starch with native starches. In the onion ring application, no significant difference was observed for weight loss between samples held up to 60 minutes; however, a significantly lower initial moisture content of fully fried samples was observed for both pea starch samples compared to the control (Table 50). Since pea starch onion rings lost more moisture than the control during full frying but the cook yield and weight loss over time were not affected, it is hypothesized that that moisture lost in pea starch onion rings was offset by fat uptake.

The onion ring pre-dust contains both instant and cook-up corn starches and twice the starch (18% - cook-up and instant) compared to the mozzarella stick pre-dust (9% - cook-up only) which is why these moisture differences may not have been observed in mozzarella sticks. The onion substrate was wet when the pre-dust was applied; therefore it is hypothesized that the instant starch in the control sample formed an immediate film around the onion which trapped excess moisture. Native pea starch may not have the ability to form a film quickly enough to avoid excess water from being absorbed into the coating system. During frying, the moisture from a coating system evaporates and voids form; the more moisture that is available, the more voids form (Ateba & Mittal, 1994). These voids then fill with oil; thus, there is a positive relationship between moisture in the coating system and oil uptake (Ateba & Mittal, 1994). Thus, native pea starch did not retain moisture or limit fat uptake as efficiently as instant corn starch in this application.

Table 50: Effect of pea starch on the physiochemical characteristics of coated onion rings

	Control[1]	Accu-Gel™[1]	Starlite™[1]	P-value
	Corn Starch	Pea Starch	Pea Starch	
Batter Viscosity[2], centipoises	675.75	661.25	626.00	0.270
Coating Pick-up, %	54.34[b]	55.64[b]	50.94[a]	0.001
Par Fry Yield, %	55.87[b]	57.68[c]	52.98[a]	0.000
Cook Yield %	70.74	70.79	69.64	0.814
Weight Loss[3] **@ 30min**, %	3.94	4.13	3.33	0.279
Weight Loss[3] **@ 45 min**, %	5.61	5.79	4.75	0.301
Weight Loss[3] **@ 60 min**, %	7.23	7.32	6.14	0.329
Moisture content[2]**, %**	38.70[b]	27.00[a]	29.99[a]	0.000

[1] Means represent quadruplicate observations
[2] Measured with Brookfield viscometer (Model RVDV-11 +PRO) with spindle 4 at 100RPM
[3] Of fully fried onion rings
[a, b, c] Means with differing superscripts are significantly different ($p \leq .05$) across rows

After temperature abuse, similar results for cook yield, weight loss, and moisture content were observed between onion ring prototypes. The moisture content of pea starch onion rings was significantly lower than the control but the cook yield and weight loss after holding remained similar (Table 51).

Table 51: Effect of pea starch on the physiochemical characteristics of temperature abused coated onion rings

	Control[1]	Accu-Gel™[1]	Starlite™[1]	P-value
	Corn Starch	Pea Starch	Pea Starch	
Cook Yield, %	75.12	73.26	69.88	0.531
WeightLoss[2] **@ 30min**, %	3.56	4.96	5.10	0.188
Weight Loss[2] **@ 45min**, %	5.06	6.50	6.78	0.297
Weight Loss[2] **@ 60min**, %	6.52	8.20	8.59	0.311
Moisture content[2], %	34.05[b]	26.54[a]	25.99[a]	0.002

[1] Means represent quadruplicate observations
[2] Of fully fried onion rings
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

B. Sensory evaluation

At 5 minutes, the trained sensory panel rated coated onion rings made with pea starch (Accu-Gel™ or Starlite™) similarly to the control onion rings for all sensory attributes; colour, crispness (moderately crispy), crunchiness (moderately crunchy), beany flavour (none), and overall quality (moderately to very high) (Table 52). After 50 minutes of holding under the heat lamp, onion rings prepared with pea starch were rated similarly to the control; although panellists commented that all onion rings held 50 minutes were lighter coloured, less crispy and less crunchy. No beany flavours were noted in onion rings after holding for 50 minutes. Thus, replacement of corn starch with pea starch did not cause any significant changes in sensory attributes of breaded onion rings and the lower moisture content of pea starch onion rings was not detrimental to overall quality.

Table 52: Effect of pea starch on the sensory characteristics of coated onion rings

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	Pea Starch	Pea Starch	P < .05
Colour	5	3.00	3.11	3.00	0.905
0=light; 6=dark	50	2.58	2.56	2.89	0.750
Crispness	5	3.22	3.22	3.22	1.000
1=not crispy; 4=very crispy	50	2.78	2.56	2.89	0.407
Crunchiness	5	3.11	3.11	2.89	0.720
1=not crunchy; 4=very crunchy	50	2.44	2.89	2.44	0.166
Beany Flavour	5	1.22	1.22	1.11	0.802
1=none; 4=extreme	50	1.22	1.44	1.33	0.764
Overall Quality	5	5.56	5.78	5.78	0.833
1=extremely low, 8=extremely high	50	5.22	5.22	5.11	0.929

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 10 person trained sensory panel

After temperature abuse, no significant differences in sensory attributes were observed (except colour) between onion rings made with pea starch and the control after holding for 5 or 50 minutes (Table 53). In general, pea starch onion rings were rated higher (darker) on the colour chart than control onion rings and they were rated even higher after holding. Fully fried Accu-Gel™ onion rings were rated significantly higher on the colour chart than Starlite™ and control onion rings after temperature abuse. However, overall quality ratings for all temperature abused onion rings were similar to those of all properly handled onion rings.

Table 53: Effect of pea starch on the sensory characteristics of temperature abused onion rings

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	Pea Starch	Pea Starch	
Colour	5	2.20[a]	3.70[b]	2.40[a]	0.000
0=light; 6=dark	50	2.30[a]	4.00[c]	3.20[b]	0.000
Crispness	5	2.80	3.40	3.10	0.171
1=not crispy; 4=very crispy	50	2.90	2.80	3.10	0.668
Crunchiness	5	2.60	2.70	2.70	0.953
1=not crunchy; 4=very crunchy	50	2.70	3.20	3.10	0.335
Off Flavour	5	1.10	1.00	1.20	0.354
1=none; 4=extreme	50	1.20	1.10	1.00	0.556
Overall Quality	5	5.90	6.10	5.50	0.191
1=extremely low, 8=extremely high	50	5.40	5.40	5.40	0.962

[1] Holding in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 10 person trained sensory panel
[a, b, c] Means with differing superscripts are significantly different ($p \leq .05$) across rows

C. Objective results

Instrumental texture data is not reported for onion ring coatings as the results were inconsistent due to inherent texture variation of the onion ring breading. When the knife attachment contacts the surface of the onion ring coating, it can encounter a large, crispy Japanese bread crumb or a smaller, denser American bread crumb. The standard errors found for texture data were too large to yield reliable results. The mozzarella stick application also encountered texture measurement challenges but onion rings contain a larger percentage of Japanese bread crumbs in the breader (60% versus 40% in mozzarella sticks) so texture variability in the onion ring coating was more pronounced.

Onion rings containing pea starch were not significantly different from the control for hue at 50 minutes or for brightness and chroma values at 5 and 50 minutes of holding under a heat lamp (Table 54). However at 5 minutes, onion rings containing Accu-Gel™ pea starch had higher (more yellow) hue values than onion rings containing Starlite™ pea starch. Panellists also commented that Accu-Gel™ pea starch containing onion rings were slightly more brown/golden compared to Starlite™ and control onion rings at 5 minutes.

Table 54: Effect of pea starch on the instrumental colour of coated onion rings

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	Pea Starch	Pea Starch	
L* (dark<light)	**5 min**	38.66	40.92	38.26	0.057
H (red<yellow)		57.96[ab]	62.00[b]	54.74[a]	0.015
C (low<high)		20.50	19.78	18.63	0.245
L* (dark<light)	**50 min**	39.22	40.43	39.49	0.640
H (red<yellow)		59.00	59.40	55.59	0.552
C (low<high)		17.59	16.85	15.69	0.339

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent 12 observations
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

After temperature abuse at both 5 and 50 minutes of hold time, no significant differences in instrumental colour were observed between pea starch onion rings and the control (Table 55). After temperature abuse, sensory panellists noted that pea starch onion rings had a darker colour than the control but instrumentally this was not observed.

Table 55: Effect of pea starch on the instrumental colour of temperature abused coated onion rings

	Time[1]	Control[2]	Accu-Gel™[2]	Starlite™[2]	P-value
		Corn Starch	Pea Starch	Pea Starch	$P \leq .05$
L* (dark<light)	**5 min**	39.09	41.35	41.26	0.265
H (red<yellow)		57.65	61.95	58.64	0.589
C (low<high)		18.85	17.39	16.03	0.085
L* (dark<light)	**50 min**	42.52	42.02	40.87	0.430
H (red<yellow)		61.03	61.81	55.86	0.360
C (low<high)		14.74	13.21	12.13	0.151

[1] Holding (minutes) in a food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent 12 observations

Overall, both pea starches were very similar in functional and sensory properties.
Accu-Gel™ pea starch was chosen for further optimization of the coated onion ring because it was also used in the French fry and mozzarella stick optimization trials.

4.6.2. Pea fraction optimization

Preliminary trials were conducted using wet fractionated pea starch (Accu-Gel™) in combination with pea flour, pea hull fibre, and pea protein from three different suppliers. Both pea prototypes were compared against a control without pea ingredients.

Three yellow pea flours were evaluated in the onion ring coatings; Best™ whole and split pea flours and Fiesta™ split pea flour. Wheat, soy, and corn flours, whey, wheat gluten, and guar gum in the coating system were fully replaced with pea flour: pre-dust (all purpose wheat flour and wheat gluten), batter (all purpose and soft wheat flour, corn flour, soy flour, whey, and guar gum), and breader (bleached wheat flour). Wheat gluten and soy flour improve adhesion of coating to the substrate, corn flour adds golden colour, and whey provides lactose (reducing sugar involved in browning reactions) and protein (coating strength and non-enzymatic browning) (Loewe, 1990). Gums control batter viscosity and improve WHC of coatings providing more flexible coatings with increased resistance to handling (Davis, 1983).

All pea flour batters required slightly higher levels of water to achieve similar cook yield and appearance as control onion rings. Control batters were hydrated at 1 part dry to 1.6 parts water. Best™ whole pea flour created a thick batter that was not process capable so it required hydration of 1 part dry to 1.8 parts water; at this ratio, a smooth, workable batter was produced. Best™ split pea flour did not require adjustment of hydration ratio from control but it produced a gritty batter that did not coat onions well. Fiesta™ split pea flour required slightly more hydration (1 part dry to 1.7 parts water) than control but at this ratio, a smooth, workable batter was produced. Best split pea flour was eliminated from the study design due to grittiness and poor onion coverage. Onion rings made with Fiesta™ had more beany flavour and lighter crispier texture compared to those made with Best™ whole pea flour. In this application, beany flavour was considered desirable as it added a savory background note that complimented the onion flavour. Good potential exists for use of either Fiesta™ split pea flour or Best™ whole pea flour in onion ring coatings.

Two dry fractioned pea hull fibres (Best™ and Exlite™) and one wet fractioned pea hull fibre (Centara™) were tested in onion ring coatings in combination with Best™ whole pea flour and Accu-Gel™ pea starch. The WHC and the particle size distribution of each pea fibre is outlined in Chapter 2 (Table 15). To make a "source of fibre" nutrient content claim, a product must provide at least 2g of fibre per serving. Preliminary trials showed that addition of 6g of fibre to reach the "excellent source of fibre" claim produced an unacceptable product. Thus, the target for fibre addition was 4g per serving so pea fibre replaced a portion of pea flour in the pea coatings. Dry milled Best™ and Exlite™ pea fibre resulted in a higher batter viscosity, darker coating colour, and more mealy texture than wet milled Centara™ pea fibre. Thus, Centara™ pea fibre was chosen for use in the optimized pea onion ring prototypes. In general, pea fibre increased viscosity of the batters, thus, batters that included pea starch, flour, and hull fibre were hydrated to 1 part dry to 1.8 parts water versus a ratio of 1 part dry to 1.6 parts water in the control.

Pea protein isolate, Propulse™ was tested in onion ring coatings as a replacement for 25% pea flour in both batter (19.8%) and breader (3.75%) coating systems in combination with Best™ whole pea flour and Accu-Gel™ pea starch. Batter containing Propulse™ was hydrated to 1 part dry to 1.8 parts water. Propulse™ produced a dark coloured, mealy textured, grassy/beany flavoured onion ring that was more expensive. Thus, no further testing with pea protein was conducted.

After preliminary trials, optimized formulas for pea/wheat and GF pea onion rings were prepared using wet milled Accu-Gel™ pea starch, Fiesta™ split pea flour, and Centara™ wet milled pea fibre as replacements for corn starch, corn, wheat, and soy flours, wheat gluten, guar gum, and whey. Optimized pea prototypes were hydrated using a ratio of 1 part dry to 1.8 parts water. Table 56 shows the pre-dust, batter, and breader formulas used for the preparation of pea containing onion rings. The GF pea prototype utilized the same formula shown in Table 56 except cracker meal in the pre-dust was replaced with ground Kinninnick crumbs while in the breader, American bread crumbs were replaced with Glutino crumbs and Japanese Panko style bread crumbs were replaced with Kinninnick crumbs. Both pea prototypes were compared against the control without pea ingredient or GF bread crumbs.

Table 56: Optimized onion ring coating containing pea ingredients and wheat bread crumbs

PRE-DUST			**Dry Mix Formula**	
			%	
Cracker meal			64.00	
Pea flour - split, Fiesta™			10.00	
Pea fibre - Centara™			5.00	
Starch - pea, native, Accu-Gel™			18.00	
Oil - vegetable, non-hydrogenated			0.50	
Salt			2.50	
Pre-dust Dry Mix Formula			**100.00**	
BATTER			**Dry Mix Formula**	**Hydrated Formula**
			%	%
Pea flour - split, Fiesta™			79.60	28.43
Pea fibre - Centara™			10.20	3.64
Starch - pea, native, Accu-Gel™			3.00	1.07
Baking powder - SAPP*			1.20	0.43
Sugar			1.50	0.54
Oil - vegetable, non-hydrogenated			1.00	0.36
Salt			3.50	1.25
Batter Dry Mix Formula			**100.00**	**35.72**
Water (4°C)				64.28
Hydrated Batter (1.8 parts water : 1 part dry mix)				**100.00**
BREADER		**Seasoning Blend**	**Dry Mix Formula**	
		%	%	
Base	Salt, hydrade	2.00	4.50	
	Garlic powder	0.50		
	Onion powder	0.80		
	Marjoram, ground	0.01		
	Cheese , romano	0.50		
	Parsley flakes	0.20		
	Basil, rubbed	0.15		
	Oregano, rubbed	0.15		
	Pepper, black, 35/70	0.20		
Pea flour - split, Fiesta™			15.00	
Pea fibre - Centara™			10.00	
Bread crumb - American style			10.00	
Bread crumb - Japanese Panko style			60.00	
Oil - vegetable, non-hydrogenated			0.50	
Breader Dry Mix Formula			**100.00**	

*Sodium acid pyrophosphate

A. Physiochemical characteristics

Batter viscosity of both pea onion ring prototypes was significantly lower than the control due to the higher hydration rate used for the test batters (Table 57). Coating pick-up and par fry yield of pea/wheat onion rings were significantly lower than the control and GF pea onion rings; however, the GF pea prototype and control were similar to each other. Higher pick-up and subsequent par fry yield in the control is attributed to higher batter viscosity while differing crumb properties likely caused the difference between pea prototypes. For fully fried onion ring prototypes, no significant differences between samples were observed for cook yield, moisture content, or weight loss over time. It is hypothesized that the additional fibre (pea fibre and pea flour) in the pre-dust of both pea prototypes may retain more moisture during full frying than instant corn starch used in the control as the moisture content of both pea onion rings were numerically higher than the control. In the onion ring starch replacement phase, native pea starch did not retain moisture or limit fat uptake as well as instant starch but pea fibre and pea flour functioned similar to instant starch when replacing wheat flour and wheat gluten. Thus, pea flour and pea fibre may be able to form a film quickly enough around the onion to avoid excess water from being absorbed into the coating system unlike native pea starch alone. No significant difference in cook yield was observed between treatments.

Table 57: Effect of pea ingredients and GF bread crumbs on the mean[1] physiochemical characteristics of coated onion rings

	Control[2]	**Pea/Wheat[3]**	**GF Pea[4]**	**P-value**
Batter Viscosity[5], cps	1333.00[b]	819.00[a]	754.00[a]	0.000
Coating Pick-up, %	55.19[b]	49.30[a]	53.75[b]	0.002
Par fry Yield, %	56.55[b]	51.47[a]	54.51[b]	0.002
Cook Yield, %	74.22	74.29	77.63	0.362
Weight loss[6] @ 30min, %	3.35	3.82	3.50	0.725
Weight loss[6] @ 45min, %	6.12	7.15	6.42	0.577
Weight loss[6] @ 60min, %	7.94	9.48	8.32	0.445
Moisture content[6], %	32.10	34.07	34.14	0.083

[1] Means represent quadruplicate observations
[2] Control made with wheat flour/gluten, corn starch/flour, soy flour, guar gum & whey
[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre and wheat bread crumbs
[4] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre and GF bread crumbs
[5] Measured with Brookfield viscometer (Model RVDV-11 +PRO) with spindle 4 at 100RPM
[6] Of fully fried onion rings
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

After temperature abuse, no significant differences in cook yield or in weight loss after 30, 45, or 60 minutes of hold time were observed between control and pea/wheat prototypes (Table 58) but the GF pea onion rings contained significantly less moisture than the control and pea/wheat onion rings. It is possible that during temperature abuse, the GF pea onion rings lost more moisture but less breading due to the small particle size of the GF crumb, thus, moisture content of the GF pea onion ring was reduced but cook yield and weight loss over time was not affected.

Table 58: Effect of pea ingredients and GF bread crumbs on the mean[1] physiochemical characteristics of temperature abused coated onion rings

	Control[2]	Pea/Wheat[3]	GF Pea[4]	P-value
Cook Yield, %	68.94	73.62	75.61	0.133
Weight loss[5] @ 30min, %	3.28	3.37	4.70	0.259
Weight loss[5] @ 45min, %	6.07	5.83	7.98	0.284
Weight loss[5] @ 60min, %	7.91	8.63	11.01	0.205
Moisture content[5], %	32.14[b]	27.69[b]	22.01[a]	0.005

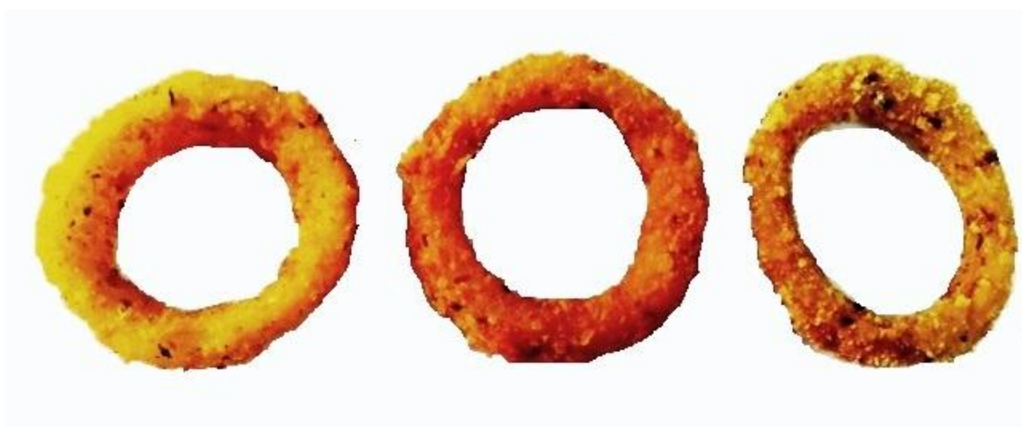
[1] Means represent quadruplicate observations
[2] Control made with wheat flour/gluten, corn starch/flour, soy flour, & guar gum
[3] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre and wheat bread crumbs
[4] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre and GF bread crumbs
[5] Of fully fried onion rings
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

B. Sensory evaluation

At 5 minutes, both pea onion ring prototypes were rated significantly higher (darker) on the colour chart and more beany in flavour than the control (Table 59) which is likely due to their higher protein content. Figure 8 shows colour differences for onion ring prototypes (control, pea/wheat, and GF pea). No differences in crunchiness of onion rings were noted. The GF pea prototype was rated significantly lower for both crispness and overall quality compared to the control and pea/wheat onion rings. The pea/wheat and control onion rings were rated similarly for overall quality; thus, darker colour and more beany flavour were not detrimental to the overall quality of onion rings. The sensory panel commented that the beany flavour added a savory background note to onion rings that was perceived as positive.

After 50 minutes of holding, both pea prototypes were rated higher (darker) on the colour chart than the control (Table 59). No significant differences in crispness, crunchiness, or beany flavour were noted between onion ring prototypes. After 50 minutes of hold time, overall quality of the GF pea prototype was again rated significantly lower than the control and pea/wheat onion ring; panellists indicated lower overall quality was due to a less crispy/crunchy texture.

Figure 8. A photograph comparing fully fried onion rings from pea ingredient optimization phase



Control **Pea/Wheat** **GF Pea**

Table 59: Effect of pea ingredients and GF bread crumbs on the mean[2] sensory evaluation characteristics of coated onion rings

	Time[1]	Control[3]	Pea/Wheat[4]	GF Pea[5]	P-value
Colour	5	3.00[a]	4.50[b]	4.10[b]	0.000
0=white; 6=brown	50	3.00[a]	4.40[b]	3.60[ab]	0.011
Crispness	5	3.30[b]	3.20[b]	2.30[a]	0.001
1=not crispy; 4=very crispy	50	2.90	2.60	2.10	0.061
Crunchiness	5	2.80	2.90	3.10	0.700
1=not crunchy; 4=extremely crunchy	50	2.90	2.70	2.40	0.181
Beany Flavour	5	1.10[a]	2.20[b]	2.10[b]	0.005
1=none; 4=extreme	50	1.40	2.00	2.00	0.253
Overall Quality	5	5.80[b]	5.20[ab]	4.60[a]	0.035
1=extremely low, 8=extremely high	50	5.70[b]	5.50[b]	4.10[a]	0.000

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 10 person trained sensory panel
[3] Control made with wheat flour/gluten, corn starch/flour, soy flour, whey & guar gum
[4] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

As expected, similar trends in sensory ratings were observed for temperature abused onion rings as for prototypes that were not temperature abused. At 5 minutes, both pea prototypes were rated higher on the colour chart than the control. The GF pea prototype was rated less crispy than the control ($p \leq 0.05$) and pea/wheat onion rings (Table 60). At 5 minutes, no significant differences in crunchiness, beany flavour, or overall quality were noted for onion ring prototypes.

After 50 minutes of hold time under a heat lamp, no significant differences in colour, crispness, crunchiness, or overall quality between temperature abused onion ring prototypes were observed. At 50 minutes, GF pea onion rings were significantly more beany in flavour than the control onion ring.

Table 60: Effect of pea ingredients and GF bread crumbs on the mean[2] sensory evaluation characteristics of temperature abused coated onion rings

	Time[1]	Control[3]	Pea/Wheat[4]	GF Pea[5]	P-value
Colour	5	2.70[a]	4.00[b]	4.00[b]	0.000
0=white; 6=brown	50	3.40	3.40	4.10	0.056
Crispness	5	3.30[b]	3.10[ab]	2.50[a]	0.046
1=not crispy; 4=very crispy	50	2.90	2.60	2.50	0.526
Crunchiness	5	2.60	2.60	3.10	0.297
1=not crunchy; 4=extremely crunchy	50	3.00	2.30	2.80	0.067
Off Flavour	5	1.60	2.10	2.00	0.259
1=none; 4=extreme	50	1.30[a]	1.70[ab]	2.40[b]	0.008
Overall Quality	5	5.70	5.20	4.80	0.095
1=extremely low, 8=extremely high	50	5.10	4.60	4.30	0.098

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent data from a 10 person trained sensory panel
[3] Control made with wheat flour/gluten, corn starch/flour, soy flour, & guar gum
[4] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

C. Objective results

Again, the instrumental texture for onion ring coatings was not reported as the results were inconsistent and not representative of texture due to inherent uneven texture of the onion ring breading.

At 5 minutes, no significant differences in instrumental colour were observed for control and test onion ring prototypes (Table 61). However after 50 minutes of holding onion rings under a heat lamp, the pea/wheat prototype was darker with lower H values (more red) compared to control and GF pea onion rings. Instrumentally, colour results for control and GF pea prototypes were similar at both 5 and 50 minute hold times. At 5 minutes, sensory panellists rated both the pea/wheat and GF pea onion rings significantly darker than control. The darker colour of the GF pea prototype was noted by the sensory panel but the colour variation of the GF bread crumbs prevented the dark colour of the GF pea onion rings from being observed instrumentally.

Table 61: Effect of pea fractions and GF bread crumbs on the mean[2] instrumental colour of fully fried coated onion rings

	Time[1]	Control[3]	Pea/Wheat[4]	GF Pea[5]	P-value
L* (dark<light)	**5 min**	45.83	46.11	46.76	0.748
H (red<yellow)		66.98	67.01	63.34	0.138
C (low<high)		15.08	14.40	14.45	0.788
L* (dark<light)	**50 min**	46.09^{b}	40.39^{a}	46.32^{b}	0.000
H (red<yellow)		15.70^{b}	13.10^{a}	15.63^{b}	0.033
C (low<high)		71.08^{b}	51.26^{a}	63.91^{ab}	0.000

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent quadruplicate observations
[3] Control made with wheat flour/gluten, corn starch/flour, soy flour, & guar gum
[4] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

After temperature abuse and 5 minutes of hold time, the pea/wheat prototype was significantly lower in H value (more red) than both the control and GF pea onion rings with significantly lower C (less colour intensity) and L values (darker) than GF onion rings. At 50 minutes, no significant differences in H or C were observed between onion ring prototypes but the GF product had a significantly higher L value (lighter) compared to the control.

Table 62: Effect of pea fractions and GF bread crumbs on the mean[2] instrumental colour of temperature abused coated onion rings

	Time[1]	Control[3]	Pea/ Wheat[4]	GF Pea[5]	P-value
L* (dark<light)	**5 min**	41.41[a]	38.81[a]	46.14[b]	0.000
H (red<yellow)		61.15[b]	45.52[a]	62.53[b]	0.000
C (low<high)		13.33[ab]	12.72[a]	15.16[b]	0.049
L* (dark<light)	**50 min**	39.45[a]	42.87[ab]	44.40[b]	0.022
H (red<yellow)		63.97	67.33	62.62	0.304
C (low<high)		17.85	18.29	16.70	0.445

[1] Holding (minutes) in food warmer (OHC-500 Heat Lamp) equipped with 250W, 120V incandescent bulbs
[2] Means represent quadruplicate observations
[3] Control made with all wheat flour/gluten, corn starch/flour, soy flour, & guar gum
[4] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & wheat bread crumbs
[5] Made with Fiesta™ split pea flour, Accu-Gel™ native pea starch, Centara™ pea fibre & GF bread crumbs
[a, b] Means with differing superscripts are significantly different ($p \leq .05$) across rows

Researchers note: In both sensory and objective testing, a large colour variation was observed for the GF bread crumbs which may have skewed colour results for the GF pea onion ring prototype. The wheat bread crumbs were a consistent golden colour, whereas, the GF bread crumbs ranged from cream to dark brown in colour.

4.7. Nutritional composition

No large nutritional differences were observed between onion rings made with corn starch and those prepared with pea starch (Accu-Gel™ or Starlite™) (Table 63). In the starch replacement phase, similar nutritional composition was expected due to the small amount of starch in the coating system (18% starch in pre-dust with pick-up only 4-10% pre-dust and 1.7% starch in hydrated batter with pick-up of 38-45% batter). The fat content per 100g of both pea starch onion rings was slightly higher than the control suggesting that pea starch onion rings absorbed more oil during frying despite lower coating pick-up for Starlite™ onion rings. Sodium content of the Starlite™ pea starch onion ring was also slightly less than the control and Accu-Gel™ onion rings due to lower coating pick-up. Table 62 shows the nutritional analysis from SGS Laboratories for the control, Accu-Gel™, Starlite™, optimized pea/wheat, and GF pea onion rings. The nutritional analysis was conducted on par fried onion rings so larger differences in fat content might be seen between fully fried onion ring prototypes.

According to the Canadian Guide to Food Labelling and Advertising (Schedule M, Table 6.1), the reference amount for onion rings (hors d'oeuvres) is 50g and the serving size can range from 25 – 100g. Based on a 50g serving, the nutritional facts tables show that pea starch replacement of corn starch results in onion rings with 10 more calories and 0.7 - 0.8g more sugar, 0.5 - 1.2g more fat, and also 20mg less sodium (Starlite™) or 2% more calcium (Accu-Gel™) depending on the type of pea starch used. The extra fat and sugar in pea starch onion rings contributed the additional 10 calories observed in these prototypes. Nutritional facts panels for onion rings containing either corn starch (control), Accu-Gel™ pea starch, or Starlite™ pea starch and for the optimized pea/wheat prototype and the GF pea onion ring are shown in Figure 9.

The optimized pea/wheat onion rings were higher in fibre, protein, calcium, and iron with less sodium but slightly more calories and fat than the control. The protein and fibre in the coating may have caused higher absorption of frying oil. Olewnik and Kulp (1990) also observed that batters containing high protein flours absorbed more fat during frying than flours with low protein levels. Since protein may play a role in fat uptake, pea flour and protein fractions may be better suited for the pre-dust and batter steps in a breaded product.

The nutritional profile of the onion ring was altered by using GF bread crumbs. Per 100g, GF pea onion rings had higher levels of sodium and calcium than control and pea/wheat onion rings with less fibre, iron, and fat compared to the pea/wheat onion rings.

Table 63. Nutritional composition of par fried onion rings per 100g[a]

		Control	Accu-Gel™	Starlite™	Pea/Wheat	GF Pea
Phase		1	1	1	2	2
Energy	kcal	246.0	263.0	258.0	271.0	267.0
Protein (Nx6.25)	g	3.7	3.8	3.8	4.6	3.9
Fat	g	13.6	14.1	14.8	16.5	14.4
Calories from Fat	kcal	122.0	127.0	133.0	149.0	130.0
Saturated Fat	g	1.1	1.1	1.2	1.3	1.1
Monounsaturated Fat	g	8.8	9.2	9.6	10.5	9.1
Polyunsaturated Fat	g	3.7	3.8	4.0	4.7	4.2
Trans Fat	g	<0.1	<0.1	<0.1	<0.1	<0.1
Cholesterol	mg	<2.0	<2.0	<2.0	<2.0	6.0
Carbohydrates	g	27.3	30.3	27.5	25.9	30.5
Total Sugar	g	4.7	5.5	5.4	4.0	4.7
Total Dietary Fibre	g	8.4	7.9	8.8	11.7	9.6
Insoluble Fibre	g	7.5	6.7	8.1	10.1	8.4
Soluble Fibre	g	<1.0	1.2	<1.0	1.6	1.2
Sodium	mg	406.9	396.7	353.0	341.0	526.0
Calcium	mg	20.1	22.6	19.6	33.0	88.0
Iron	mg	1.8	1.7	1.7	2.0	1.0
Moisture	g	54.0	50.5	52.7	51.8	49.2
Ash	g	1.4	1.3	1.2	1.2	2.0
Vitamin A	IU	<10.0	<10.0	<10.0	<10.0	<10.0
Vitamin C	mg	<1.0	<1.0	<1.0	<1.0	<1.0

[a] Results were obtained from SGS Laboratories (Vancouver, BC)

Nutritional analysis of par fried onion rings was also conducted after two freeze-thaw cycles to determine if temperature abuse had an effect on the nutritional composition. Results are not shown because there were no observable differences between par fried onion rings after temperature abuse.

Figure 9: Nutritional fact tables for control and test samples of breaded, par fried onion rings

Breaded Onion Rings – Control
(Modified corn starches, wheat flour, etc.)

Nutrition Facts / Valeur nutritive	
Serving Size (50 g) / Portion (50 g)	
Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 120	
Fat / Lipides 7 g	**11** %
Saturated / saturés 0.5 g + Trans / trans 0 g	**3** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 200 mg	**8** %
Carbohydrate / Glucides 14 g	**5** %
Fibre / Fibres 4 g	**16** %
Sugars / Sucres 2 g	
Protein / Protéines 2 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	0 %
Iron / Fer	6 %

Breaded Onion Rings
(Accu-gel™ pea starch)

Nutrition Facts / Valeur nutritive	
Serving Size (50 g) / Portion (50 g)	
Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 130	
Fat / Lipides 7 g	**11** %
Saturated / saturés 0.5 g + Trans / trans 0 g	**3** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 200 mg	**8** %
Carbohydrate / Glucides 15 g	**5** %
Fibre / Fibres 4 g	**16** %
Sugars / Sucres 3 g	
Protein / Protéines 2 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	2 %
Iron / Fer	6 %

Breaded Onion Rings
(Starlite™ pea starch)

Nutrition Facts / Valeur nutritive	
Serving Size (50 g) / Portion (50 g)	
Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 130	
Fat / Lipides 7 g	**11** %
Saturated / saturés 0.5 g + Trans / trans 0 g	**3** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 180 mg	**8** %
Carbohydrate / Glucides 14 g	**5** %
Fibre / Fibres 4 g	**16** %
Sugars / Sucres 3 g	
Protein / Protéines 2 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	0 %
Iron / Fer	6 %

Optimized Pea/Wheat Breaded Onion Rings
(Accu-gel™ pea starch, Fiesta™ pea flour & Centara™ pea fibre)

Nutrition Facts / Valeur nutritive	
Serving Size (50 g) / Portion (50 g)	
Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 140	
Fat / Lipides 8 g	**12** %
Saturated / saturés 0.5 g + Trans / trans 0 g	**3** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 170 mg	**7** %
Carbohydrate / Glucides 13 g	**4** %
Fibre / Fibres 6 g	**24** %
Sugars / Sucres 2 g	
Protein / Protéines 2 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	2 %
Iron / Fer	8 %

Gluten-Free Pea Breaded Onion Rings
(Accu-gel™ pea starch, Fiesta™ pea flour & Centara™ pea fibre)

Nutrition Facts / Valeur nutritive	
Serving Size (50 g) / Portion (50 g)	
Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 130	
Fat / Lipides 7 g	**11** %
Saturated / saturés 0.5 g + Trans / trans 0 g	**3** %
Cholesterol / Cholestérol 5 mg	
Sodium / Sodium 260 mg	**11** %
Carbohydrate / Glucides 15 g	**5** %
Fibre / Fibres 5 g	**20** %
Sugars / Sucres 2 g	
Protein / Protéines 2 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	4 %
Iron / Fer	4 %

Pea ingredient utilization can improve the nutritional profile of onion rings. In particular, an "excellent source of fibre" claim can be made for the pea/wheat onion rings as they contain 6g of fibre per 50g serving while GF pea, pea starch, and control onion rings can claim "good source of fibre" with 4-5g of fibre per 50g serving.

4.8. Cost implications

Prices for pea ingredients and traditional coating ingredients are shown in Table 64. Native pea starch was estimated to cost an additional $0.11-0.13 CDN/lb over modified corn starch. Pea flour was less expensive than wheat, corn, and soy flours and pea flour and hull fibre are both less costly than wheat gluten, guar gum, and whey.

Table 64: Coating ingredient price comparison (excluding crumb)

Ingredient	CDN $/lb
Wheat Flour – soft*	$0.41
Wheat Flour – all purpose*	$0.43
Corn Flour – yellow*	$0.50
Soy Flour	$0.50
Pea Flour	$0.40
Cook-up Corn Starch*	$0.82
Instant Corn Starch*	$0.84
Native Pea Starch**	$0.95
Guar Gum*	$4.00
Wheat Gluten*	$1.20
Whey	$1.26
Pea Fibre**	$0.62

* Commodity price estimates per national vendors, March 2012
** Average price based on Canadian pea fraction suppliers, January 2012

Table 65 shows the estimated cost of ingredients for the onion ring coatings (control, both pea starch and optimized pea/wheat). Based on ingredient cost per pound of coating, the pea starch onion ring was $0.02 CDN/lb more than the control, whereas, the optimized pea/wheat onion ring was $0.01 CDN/lb less.

Table 65: Dry pre-dust, hydrated batter, and dry breader cost comparison (CDN $/lb) excluding crumb

	Control[1]	Pea Starch[2]	Optimized Pea/Wheat[3]
Starch	Corn	Pea	Pea
Flour	Wheat/Corn	Wheat/Corn	Pea
Fibre	--	--	Pea
Soy, gluten, gum, & whey	Soy/Gluten/Gum/ Whey	Soy/Gluten/Gum/ Whey	--
Pre-dust	$0.251	$0.274	$0.242
Hydrated Batter	$0.165	$0.167	$0.147
Breader	$0.108	$0.108	$0.122
Price difference from control	**$0.000**	**+$0.025**	**-$0.013**

[1] Control made with all purpose & soft wheat flours, corn flour, soy flour, gluten, guar gum, whey & modified corn starches
[2] Modified corn starch was fully replaced by pea starch
[3] Made with Fiesta™ split pea flour, Accu-gel™ pea starch, Centara™ pea fibre, & wheat bread crumbs

4.9. Conclusions – Onion rings

Onion rings containing native pea starch (Accu-Gel™ or Starlite™) as 100% replacement for cook-up and instant corn starches had similar sensory and nutritional properties to the control. Both pea starches did not affect batter viscosity but dry milled Starlite™ pea starch onion rings had significantly less coating pick-up and par fry yield than the control and Accu-Gel™ onion rings. Pea starch and control onion rings had similar cook yields because pea starch prototypes lost moisture during frying but absorbed more oil to compensate.

Freshly fried onion rings made with pea starch in the coating were similar to the control onion rings for the following sensory characteristics: overall quality (moderately to very high), colour, beany flavour, crispness (moderately crispy), and crunchiness (moderately crunchy). Thus according to the sensory panel, the lower moisture of pea starch onion rings did not affect overall quality.

The nutritional facts table of both pea starch onion rings was similar to that of the control but the ingredient label has increased consumer appeal due to the replacement of modified corn starches with native pea starch.

Utilization of pea starch, flour, and hull fibre in onion ring coatings to fully replace traditional coating ingredients can result in lower cost onion rings with improved nutritional properties and a cleaner label with comparable sensory quality to the control. In addition to the optimized pea/wheat crumb onion ring, a GF pea version was also produced; however, better quality GF bread crumbs are required. Due to adhesion and thickening properties of pea flour and fibre, several functional ingredients (soy flour, wheat gluten, guar gum, and whey) were removed from the formula resulting in a 'cleaner' label and a less expensive coating.

The optimized pea/wheat onion ring had lower batter viscosity, coating pick-up, and par fry yield compared to the control but it had similar cook yield, weight loss over time, and moisture content after full frying. Compared to the control onion ring, the pea/wheat prototype was more golden/darker in colour and more beany in flavour. However, the beany flavour added a savory, roasted background note that complimented the flavour of the onion.

Based on the nutritional facts tables, the par fried optimized pea/wheat onion ring had more fibre, calcium, iron, fat, and calories but less sodium than the control onion ring. An "excellent source of fibre" nutrient content claim can be made for the optimized pea/wheat onion ring whereas, in the control onion ring, only a "good source of fibre" claim can be made.

The cost to replace modified corn starch with native pea starch is $0.02 CDN more per pound of coating based on current pea starch prices. By utilizing pea ingredients rather than traditional ingredients in the onion ring coating, a cost savings of $0.01 CDN/lb of coating could be obtained.

4.10. Opportunities & challenges – Onion rings

Opportunities and challenges associated with utilizing pea ingredients in three step breading applications for onion rings or similar food products.

Opportunities for pea ingredients

1) Enhanced colour: yellow pea flour provides a golden colour and can replace corn flour.

2) Fibre claim: 'excellent source of fibre' claim can be made with addition of pea starch, flour, and hull fibre.

3) Gluten-free: pea starch, flour and hull fibre can be used to develop a GF product in conjunction with GF bread crumbs and cracker meal. Product quality is impacted by quality of the GF bread crumbs.

4) Cleaner label: pea starch, flour and hull fibre can be used to replace functional ingredients (modified corn starch, soy flour, guar gum, wheat gluten, and whey) to shorten the ingredient listing and provide more 'natural' breaded products.

5) Improved nutritional profile: pea starch, flour, and hull fibre can be used to increase fibre, calcium and iron.

6) Enhanced flavour: pea flour contributes complimentary savory, background notes.

7) Ingredient cost reduction: pea flour and hull fibre can replace more expensive ingredients (wheat, corn, and soy flours, guar gum, wheat gluten, and whey) and offset the slightly higher cost of pea starch for an overall cost reduction.

8) Allergen free: pea flour can replace allergenic ingredients derived from soy and milk (soy flour and whey).

Challenges for pea ingredients:

1) GF bread crumbs: development of a high quality GF breaded product is limited by the quality of existing GF bread crumbs.

2) Moisture retention: pea starch in the coating can reduce moisture content of fully fried product but moisture differences did not affect overall quality.

3) Fat absorption: pea starch, flour and hull fibre in the coating can increase fat absorption of the par fried product.

4) Ingredient cost: pea starch is currently more expensive than modified corn starch.

5.0. OVERALL CONCLUSIONS

Yellow pea ingredients can aid in the generation of nutritious, high quality battered and breaded food products with potential for GF status and other health benefits. Peas are comprised of approximately 50% starch, 25% protein, and 15% fibre; starch is considered a by-product of pea fractionation compared to high demand protein and fibre. Thus, if utilization of pea starch was adopted by the batter and breading industry, pea processors would benefit. Pea starch, flour and fibre each possesses unique physiochemical, sensory, and nutritional properties which can benefit manufacturers and consumers of battered and breaded food products. Selecting the correct pea ingredient(s) and location in the coating, as well as optimizing usage levels is important for successful application in the food industry.

This project has shown that pre-dust, batter, and breading dry mixes can be produced using pea ingredients (starch, flour and hull fibre) to fully replace traditional wheat and corn ingredients and functional ingredients (gums, gluten, caramel colour, whey, and soy flour) in battered French fries, breaded mozzarella sticks, and breaded onion rings. Pea ingredients also offer non-allergenic, 'clean' label alternatives to traditional coating ingredients. Nutritional and sensory properties and ingredient cost of the final coatings containing pea ingredients were similar or improved compared to traditional battered and breaded products.

Key findings for use of pea starch in coatings:

- Native pea starch thickens mozzarella stick and French fry batters more than modified corn starch. Pea starch may be beneficial in decreasing cost of batter systems as additional water may be added or thickening ingredients may be removed to obtain desired viscosity.

- The addition of pea starch can yield mozzarella sticks with higher cook yields and softer cheese than those with corn starch.

- Native pea starch may not be a good alternative for instant starch in the pre-dust of high moisture foods like onion rings. However, native pea starch functions well in the pre-dust as a replacement for cook-up corn starch.

- Dry milled pea starch produced French fry batter with higher viscosity than batter containing wet milled pea starch. Thus, wet milled pea starch may be better suited for thinner batters (ie. battered French fries) while dry milled pea starch may be better utilized for thicker batters (ie. tempura chicken nuggets).

- Dry milled pea starch produced crisper battered French fries and breaded mozzarella sticks than modified corn starch and wet milled pea starch.

- Mozzarella sticks with dry milled pea starch had higher levels of beany flavour than those with wet milled pea starch.

- Dry milled pea starch provides better moisture retention in breaded mozzarella sticks that have been fully fried than modified corn starch and wet milled pea starch.

Key findings for use of pea starch with pea flour and fibre in coatings:

- Pea flour that is equal to or less than 425 microns in size with WHC equal to or less than 100% results in process capable batter. If using flour with a larger granule size and/or higher WHC, batter hydration may need to be increased to obtain a workable batter viscosity (15-40 seconds, Stein Cup / 400-600 centipoise, Brookfield viscometer).

- Beany flavour intensity is influenced by the combination of pea ingredients and fractionation process; coatings with dry milled pea starch and split pea flour contribute more beany flavour than other pea ingredients.

- Beany flavour in coatings can be a positive or negative attribute depending on the type of coating and/or substrate. If the coating is thin like in the French fry application or if the substrate has a strong flavour and the coating system is heavily spiced like in onion ring application, the beany flavour may be positively perceived.

- Pea flour contains higher levels of protein, fibre, calcium, and iron than traditional corn and wheat flours, thus, it enhances the nutritional profile of battered and breaded products that are prepared with it.

- Due to the high dietary fibre content of peas, fibre content claims can be made for coated products that contain pea flour and hull fibre. For onion rings and mozzarella sticks, “excellent source of fibre” and “source of fibre” claims can be made, respectively.

- Use of yellow pea flour in batter and breadings can increase golden colour. Degree of browning can also be modified depending on the flour selected.

- Acceptable GF battered and breaded food products can be produced by substituting pea ingredients (which are inherently GF) for wheat flour and gluten.
- Due to higher batter hydration ratios and replacement of expensive ingredients (gums, soy flour, gluten, Maillose®, etc), a cost saving, and a cleaner, more ‘green’ ingredient list can be obtained through the use of yellow pea ingredients.

- Location of pea flour and fibre within the coating system can affect oil uptake in breaded products. It may be possible to minimize fat absorption by incorporating the pea ingredients closer to the substrate.

- Pea flour and pea hull fibre can successfully replace allergenic ingredients like soy and milk (soy flour and whey) in breaded onion rings.

6.0. FURTHER RESEARCH

The Canadian pea industry can use the results from this study as a marketing tool to promote pea flour and its fractions as key ingredients to the food industry and to aid their successful utilization in battered and breaded food products. This study has also revealed research gaps to be addressed in order to maximize the use of pea ingredients by the food industry.

- Investigate the development of a commercial GF bread crumb and cracker meal using pea ingredients. This would provide much needed ingredients for GF pre-dust and breading systems.

- Examine whether location of pea protein only in the pre-dust of the coating system could minimize colour development, mealy texture, rough surface texture, and beany flavour while maximizing adhesion and nutritional properties.

- Investigate suitability of pre-gelatinized pea starch and/or pre-cooked pea flour (roasted or steamed) in batter and breading applications.

- Examine the potential for pea flour in microwavable fried products as it has an inherent yellow hue. Microwave cooked food is typically pale in colour because there are no browning reactions (caramelization or Maillard reactions) occurring so additives, colours, and spices are added to offset the pale colour.

- Examine the potential for pea starch in the microwavable fried foods. High amylose corn starch is beneficial for microwave reconstitution applications so pea starch could also be suitable as it is high in amylose.

- Investigate pea flour and hull fibre location within the coating to potentially reduce fat absorption.

- Research the use of pea cell wall fibre in the coating system as other researchers have noted that it absorbs less oil than hull fibre.

- Investigate a more reliable instrumental test to measure texture of breaded products.

- Determine the gelatinization temperature of pea, wheat, and corn ingredients to strengthen findings.

- Investigate the use of pea fibre as a substitute for instant corn starch because both ingredients have immediate thickening properties.

7.0. PROJECT IMPACT & INDUSTRY INTERACTION

The pea ingredient suppliers (Parrheim Foods, Best Cooking Pulses, and Nutri-Pea Ltd.) have been integral to this project's success. They have provided pea ingredients for utilization in the study and relevant information for the ingredients. All three commercial pea suppliers would be key beneficiaries of these new applications for pea ingredients. Newly Weds Foods provided starting formulas and processes, technical knowledge and ingredients to make the coatings, thus ensuring this research is applicable to industry. The report will be shared with the industry partners (Newly Weds Foods, Nutri-Pea Limited, Parrheim Foods, and Best Cooking Pulses) and they can extract information for use in their marketing.

The Manitoba Pulse Growers Association (MPGA), one of the project funders, publishes a trade Journal entitled *Pulse Beat.* An article discussing the French fry portion of the research was published in the spring 2011 edition of *Pulse Beat* (Figure 10). A second article on the breaded mozzarella stick and onion ring research is expected to be published in the fall 2012 edition of *Pulse Beat.*

Figure 10: Pulse Beat article - Pea ingredients in French fries, March 2011

GLUTEN-FREE BATTERED FRENCH FRIES

Peas offer a Novel Approach

Laura Sawyer
Food Development Centre

Pulses are gaining momentum as healthy, popular food choices because they are low in fat and high in protein and fibre. Recent research reports conclude that pulses play a role in weight management, and may be helpful in the control and prevention of diseases like diabetes and heart disease.

Pulses and pulse flours are also gluten free making them an ideal fit for the rapidly growing "functional" and "gluten-free" food markets. According to a recent report from Packaged Facts, the health and natural foods market in North American exceeds $22 billion USD annually (2004) and the gluten-free market has grown at an average rate of 28 per cent annual since 2004.

Traditionally peas have been marketed for human consumption as bulk products and for animal feed. Their popularity has been limited in the food sector because they are hard-cooking and time consuming. According to Sheri Strydhorst, executive director of the Alberta Pulse Growers Commission, the majority of Canadian peas are exported to two price-sensitive customers, India and China. Market-dependence is a major concern and a driving force to diversify through innovative utilization of peas and pea fractions which appeal to North American and European consumers. Consumers in these markets crave the health and environmental benefits of pulses in culturally acceptable food products.

Several pulse milling technologies are available in Canada and pea flour and pea fractions such as pea protein, pea starch, and pea fibre are now available in addition to whole and split forms. The availability of commercial pea flours and fractions gives rise to unlimited opportunities for peas in many food applications.

Pea protein and fibre have been studied and utilized in bakery, cereal-based, and health food products because consumers demand higher protein and fibre. However, demand for pea starch is low and the starch fraction is often underutilized. Pea starch has excellent gelling, fat limiting, water binding properties and the potential to be a functional ingredient in food applications.

A research project conducted by the Food Development Centre in Portage la Prairie, MB and sponsored by Alberta Crop Industry Development Fund Ltd, Alberta Pulse Growers, Pulse Canada, Manitoba Pulse Growers, and Parrheim Food is investigating the use of pea fractions (starch, flour, fibre, and protein) in batter and predust coatings of value-added products. Three food applications will be assessed: French fries, mozzarella sticks, and onion rings. The suitability and benefits of using pea starch in combination of other pea fractions to replace traditional corn starch and wheat flour will be evaluated.

RESEARCH INSIGHT: BATTERED FRENCH FRIES

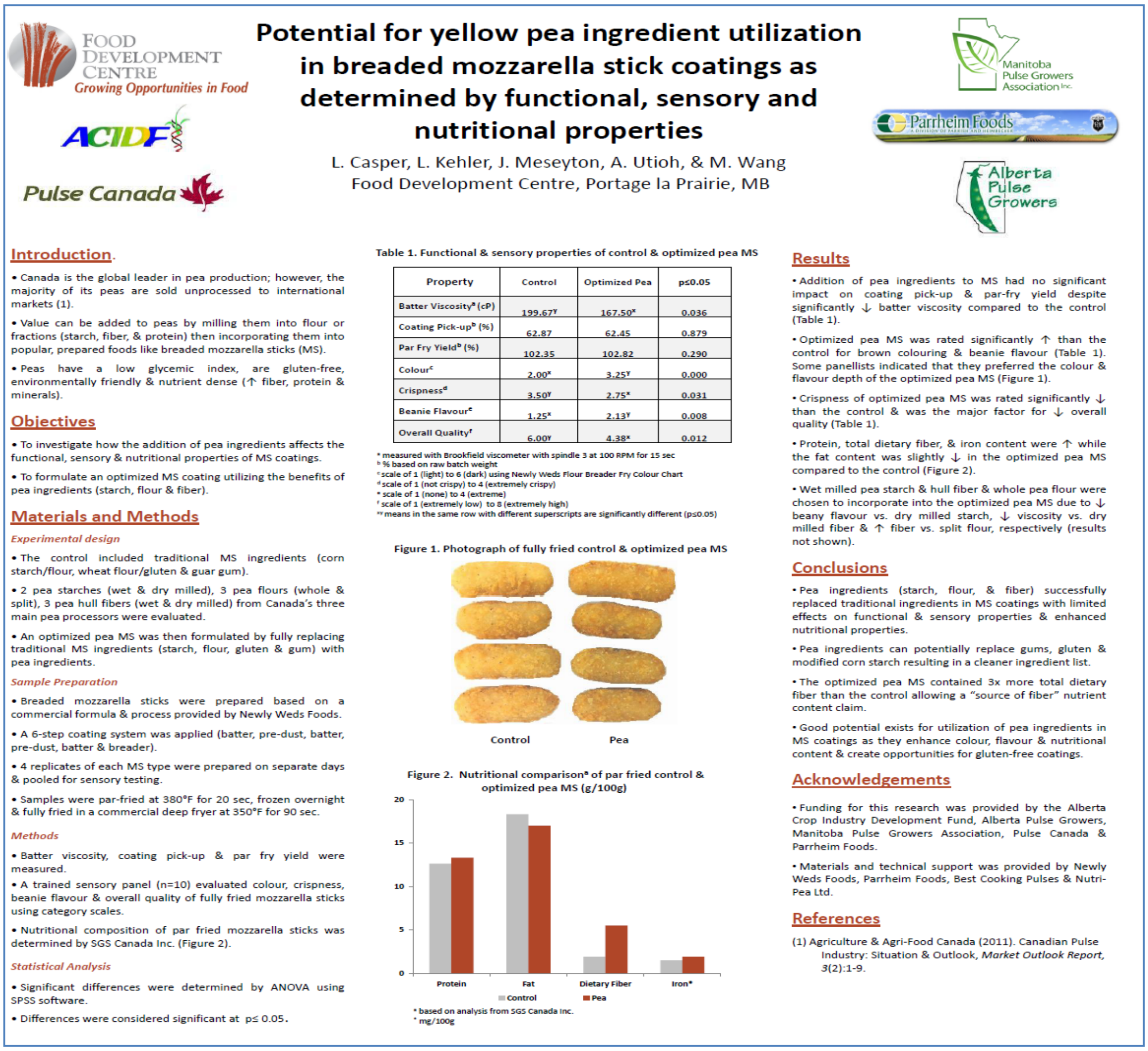
According to Agriculture and Agri-Food Canada, frozen French fries are the largest export in the frozen food category. Many restaurants today serve battered French fries as a low-cost alternative to natural (un-battered) French fries. Pea fractions offer a Canadian-made, affordable, environmentally friendly way to produce gluten-free battered French fries.

continued on page 36

A poster on the mozzarella stick portion of the study was also presented at the 50th Canadian Institute of Food Science and Technology conference in Niagara Falls on May 28, 2012 (Figure 11). Best Cooking Pulses covered a portion of the travel expenses to enable the researcher to present the poster and attend the conference. While at the

Institute of Food Technologists conference, Pulse Canada also shared the poster with participants. Currently, the poster is on display at the Food Development Centre in Manitoba.

Figure 11: CIFST Poster – Pea ingredients in mozzarella sticks, May 2012



Pulse Canada also generated a fact sheet which highlighted advantages of using pea ingredients in batters and breadings from the first project (chicken nuggets, fish sticks, and chicken breasts). A second fact sheet from findings of the current study of pea ingredients on French fries, mozzarella sticks, and onion rings is also being generated.

FDC will continue to promote the project results through presentation of products to clients at the Centre and by accepting invitations from pulse growers and processors to present the project findings.

8.0. FINANCIAL UPDATE

The following partners provided financial contributions to the project:

Industry Partner	**Contribution**
Alberta Crop Industry Development Ltd.	$96,161
Pulse Canada	$65,000
Alberta Pulse Growers Commission	$24,161
Manitoba Pulse Growers Association	$5,000
Parrheim Foods Ltd.	$2,000
Total	**$192,322**

The detailed financial distribution based on project activities is attached as a separate document to this narrative report.

9.0. REFERENCES

Agriculture and Agri-Food Canada (2000). Dry peas: situation and outlook. *Bi-weekly Bulletin.* Retrieved March 20, 2012, from http://www.agr.ca/policy/winn/biweekly/English/biweekly/volume13/v13n07e.html.

Altunakar, B., Shin, S. & Sumna, G. (2004). Functionality of batters containing different starch types for deep-fat frying of chicken nuggets, *European Food Research Technology, 218*: 1318-1322.

Anderson, E. & Berry, B. (2003). Effects of inner pea fibre on fat retention and cooking yield in high fat ground beef, *Food Research International, 31*, 689-694.

Ateba, P. & Mittal, G. (1994). Modeling the deep-fat frying of beef meatballs, *International Journal of Food Science & Technology, 29*:429-440.

Davis, A. (1983). Batter and breading ingredients. In D.R. Suderman and F.E. Cunningham (Eds.), *Batter and Breading Technology* (pp. 15-23). New York: AVI-Van Nostrand.

Fiszman, S. (2009). Quality of battered or breaded fried products. In S. Sahin and S. G. Sumnu (Eds.), *Advances in Deep Fat Frying of Foods* (pp. 243-261). Boca Raton: CRC Press.

Francis, F. & Clydesdale, F. (1975). *Food Colourimetry: Theory and Applications.* Westport: Avi Publishing Company Inc.

Heng, L., van Koningsveld,G., Gruppen, H., von Boekel, M., Vincken, J., Roozen, J., & Voragen, A. (2004). Protein-flavour interactions in relation to development of novel protein foods, *Trends in Food Science and Technology, 15*:217-224.

Kuntz, L. (1997). The great cover-up: Batters, breadings, and coatings, *Food Product Design.* Retrieved on June 11, 2012 from http://www.fooproductdesign.com/articles/1997/04/.

Loewe, R. (1990). Ingredient selection for batter systems. In K. Kulp & R. Loewe (Eds.), *Batters and Breadings in Food Processing* (pp. 11-28). St. Paul: AACC.

Mohamed, S., Hamid, N., & Hamid, M. (1998). Food components affecting the oil absorption and crispness of fried batter, *Journal of Science, Food & Agriculture, 78*:39-45.

Olewnik, M. & Kulp, K. (1990). Factors affecting performance characteristics of wheat flour in batters. In K. Kulp & R. Loewe (Eds.), *Batters and Breadings in Food Processing* (pp. 93-116). St. Paul: AACC.

Packaged Facts (2011). Gluten-free foods and beverages in the US. Retrieved March 22, 2012, from www.companiesandmarkets.com/Market/Food-and-Drink/Market Research/Gluten-Free-Foods-and-Beverages-in-the-US-3rd-Edition/RPT868876.

Packaged Facts (2010). Functional foods and drinks: A global strategic business report. Retrieved on March 22, 2012, from www.companiesandmarkets.com/Market/Food-and Drink/MarketResearch/Functional-Foods-and-Drinks-A-Global-Strategic-Business Report/RPT649070.

Patterson, C., Maskus, H., & Bassett, C. (2010). Fortifying foods with pulses, *Cereal Foods World, 55*(2): 56-62.

Patterson, C. (2003). Research overview on grain legume fractions, *Canadian Pulse Crops* Association, PhD Thesis.

Pulse Canada. (2007). Statistics. Retrieved October 10, 2011, from http://www.pulsecanada.com/statistics.

Ratnayake, W.S., Hoovera, R. & Warkentine, T. (2002). Pea starch: Composition, structure and properties – A review, *Starch*, 217-234.

Swanson, B. G. (1990). Pea and lentil protein extraction and functionality, *Journal of the American Oil Chemists' Society*, 276-280.

Texture Technologies Corp. TA.XT2 Texture application study: Shoestring French fries, study #29W, Scarsdale, NY. Personal Communication. Marc Johnson marcj@texturetechnologies.com.

Texture Technologies Corp. TA.XT2 Plus application study: Acoustic testing of shoestring French fries, Study #29WA, Scarsdale, NY. Personal Communication. Marc Johnson marcj@texturetechnologies.com.

United States Standards for Grades of Potatoes for Processing. Retrieved July 6, 2010, from http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5050438.

USA Dry Pea & Lentil Council (2010). Dry peas, lentil, and chickpeas as functional ingredients in flour milling, *Pulse Processing Technical Manual*, Retrieved June 25, 2012 from http://www.pea-lentil.com/technical-manual.

Vose, J. (1977). Functional characteristics of an intermediate amylose starch from smooth seeded field peas compared with corn and wheat starches; *Cereal Chemistry, 54*(5):1141-1151.

10.0. PROJECT PARTNERS

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APPENDIX A: LITERATURE REVIEW

TABLE OF CONTENTS

1.0 INTRODUCTION 124

2.0 PEAS 125

2.1 Nutritive value 125
2.2 Processing 125
2.3 Coatings 126
2.3.1 Pre-dust 126
2.3.2 Batter 126
2.3.2 Breading 127
2.4 Composition 128
2.4.1 Flour and Starch 128
2.4.2 Gums 129
2.4.3 Leavening Agents 129
2.5 Deep Frying 130

3.0 FRENCH FRY 131

3.1 Market and Production 131
3.2 Processing 131

4.0 ONION RING 132

4.1 Market and Production 132
4.2 Processing 132

5.0 MOZZARELLA STICK 133

5.1 Market and Production 133
5.2 Processing 134

6.0 QUALITY ASSESSMENT 134

6.1 Viscosity 134
6.2 Coating Pick-up 135
6.3 Cooking yield 135
6.4 Colour 135
6.5 Texture: Crispness 135
6.6 Freeze-thaw Stability 137
6.7 Heat-lamp Stability 137
6.8 Sensory 137

7.0 COMMON PROCESSING PROBLEMS 138

8.0 PEA INGREDIENTS 139

8.1 Pea Starch 139
8.2 Pea Flours 140
8.3 Pea Fibre 141

REFERENCES 141

1.0 INTRODUCTION

Canada is one of the largest producers and exporters of pulses worldwide with the majority of production occurring in the Prairie provinces (Saskatchewan Agriculture & Food, 2001). Pulse production in Canada increased from 3.7 million tonnes in 2006 to 5.2 million tonnes in 2009 (Agriculture & Agri-Food Canada, 2010). The most produced and exported pulse, dry pea, reached 3.4 million tonnes in 2009 which accounted for 65% of total pulse production (Agriculture & Agri-Food Canada, 2010). Dry pea exports increased by 75% ($461 million in 2006 to $806 million in 2009) due to the expansion of the market in India (Agriculture & Agri-Food Canada). Export sales to Indian markets were estimated at $1.1 billion (Agriculture & Agri-Food Canada, 2010).

Peas are primarily used for human consumption and high quality animal feed. Peas can be cooked and eaten whole as a vegetable or incorporated into other foods as an ingredient (Agriculture & Agri-Food Canada, 2010). Peas are available in whole and split flours, as well as other fractions, such as protein, starch and fibre. Functionality of pea fractions has been studied extensively. Pea starch, the most abundant fraction in pea flour, has excellent gelling, fat limiting and water binding properties (Han and Tyler, 2003). Potential exists for pea fractions to be utilized in water-flour systems (batter) to create value-added products that are high in both protein and fibre.

Batter or bread crumb coated food products are attractive to a number of consumers due to their unique flavour, colour and texture. From the perspective of a food grower or processor, coating adds value to ordinary foods and is appreciated more by consumers. Changes in lifestyle and popularity of convenient, frozen foods have driven the development of coated products. Currently the coated frozen foods market is growing steadily. In the US, the volume of battered and breaded food products was 1.14 billion pounds per year (Shukla 1993). However, fried foods contain high levels of fat and can absorb as much as 490 grams of oil per kilogram of finished product weight (Makinson et al. 1987). Consumption of high fat food is more likely to develop a number of chronic diseases such as obesity, coronary heart disease, cancer, diabetes and hypertension. According to Fiszman, automation of manufacturing, innovations in cooking methods, the demands for more sophisticated foods, diversification, and a concern to develop healthier products that contain less fat are the factors that dominate the latest research trends in this area (2009). Pea fractions have the potential to boost the nutritional profile of breaded and battered food products. Therefore, this research focuses on the application of pea fractions in batter or breaded food products, namely, French fries, Mozzarella sticks and onion rings.

2.0 PEAS

2.1 Nutritive value

Peas *(Pisum sativum)* are important components in the human diet. Peas are a good source of protein, carbohydrates and micronutrients such as vitamins and minerals. Peas have been identified as a low glycemic index food due to their high level of resistant starch. Diets rich in peas are associated with health benefits such as increased satiety, reduced blood glucose levels, improved heart health and reduced risk of colon cancer (Chibbar et al. 2010). In addition, peas do not contain gluten, making them a good option for people with a gluten allergy or celiac disease. According to Canadian Celiac Disease Association, it is estimated that 1 in 133 persons in Canada suffer from celiac disease (2011). There is no cure for celiac disease and people who suffer from it must follow a strict GF diet. Therefore, peas have the potential to fulfill the growing market demand for healthy and GF food products.

2.2 Processing

Commercially available pea ingredients include pea flour, pea protein, pea starch and pea fibre which can be obtained through either dry or wet milling. In the case of dry milling, whole peas are dehulled first and then are put through a mill. The final ingredients are generated by air classification based on particle size. For wet milling, peas are first dehulled and ground. Proteins are then extracted via solubilization in water, acid and/or alkali yielding starch and fibre as by-products. Wet milling generates more pure separation of protein and starch than dry milling procedures.

2.3 Coatings

Pre-dusts, batters and breadings can all be referred to as coatings as they all adhere to the surface of a food substrate. Pre-dusts are typically made up of finely ground cereal based ingredients which absorb any excess water on the food substrate; thus, aid in adhesion of any additional coatings (Yang & Chen, 1979). Batters are defined as "liquid mixtures composed of water, flour, starch and seasonings into which food products are dipped prior to cooking (Cunningham & Suderman, 1981). Breading is defined as "dry mixtures of flour, starch and seasonings of coarse particle size applied to the moistened or battered food products prior to cooking" (Cunningham & Suderman, 1981). Based on different food substrates and variable coating pick-up requirements, three or more steps of pre-dust, battering and breading can be used.

2.3.1 Pre-dust

Pre-dusts are typically the first material applied to a moist substrate that is to be coated. They aid in adhesion of coatings to the substrate by absorbing excessive water. The most widely used pre-dusts are flour or dry batter mixes. Pre-dust is also used as a flavour carrier as it aids in retaining flavour that is typically lost during frying.

2.3.2 Batter

There are two types of batters widely used: adhesive/interface batters and tempura batters.

2.3.2.1 Adhesive batter

The majority of adhesive batters are used on substrates that are to be breaded as they aid in adhering the breader. In order to be adhesive, this batter must be sticky; thus, the viscosity must be carefully controlled. Normally adhesive batter has a low to medium viscosity. Batter with low viscosity requires overflow configuration, whereas medium viscosity batters require a total submersion system. Chemical leavening is normally not used.

2.3.2.2 Tempura-Type/Leavened Batter

Tempura battered food products do not typically have a breader added; thus, the batter is the final step in these types of coated food products. They contain a leavening agent which causes gas to be released to form a light sponge-like structure which facilitates vapour evaporation during frying and contributes to the crispness of the final product. It also contains wheat flour, corn flour, starch and has a high viscosity. The batter smoothness and thickness determines the acceptability of final products. After frying, a tempura batter needs to have a smooth, uniform, visually attractive external layer and have good adhesion to the substrate. Due to the high viscosity of this type of batter, the substrate must be submersed into batter. Tempura batters should have a solids to water ratio of 1:1.1 (Barbut, 2002) at a temperature of 4°C and batter pick-up of 20-40%.

2.3.2 Breading

Breading is applied to food substrates after adhesive battering. It can be a three-step process (>25% pick-up) including pre-dust, batter and breading; or a two-step process (20-30% pick-up) without pre-dusting. A variety of breading materials are available. One or more crumb types, flours, starches and flavouring materials such as herbs, spices, nuts and seeds can be used alone or in combination.

Commercial crumbs are available in different forms. The most widely used crumbs in North America include reclaimed breadcrumbs (prepared from ordinary leftover bread), and industrial crumbs (baked specifically for coating). Industrial crumbs are available with different properties, such as Japanese style crumbs (flake-like, open, porous), cracker meal (low oil absorption, high fry tolerance), flour breader (good flavour carrier, high fry tolerance) or extruded crumbs (low cost, high output).

2.4 Composition

Ingredients typically used in batter or breadings include flours (wheat, corn, rice), starches, leavening agents, gums, flavourings and seasonings. The concentration and functionality of each ingredient used in a typical batter formulation is shown in Table 1.

Table 1: Ingredients functionality in batter formulations

Ingredient	Functionality
Wheat flour	Creates body and structure and increases batter viscosity
Corn flour	Provides crispness and golden brown colour
Starches	Increases tenderness and crunchiness and improves crispness
Leavening agents	Allows moisture release and traps air to create lighter, more crispy coatings
Gums	Provides viscosity control and participates in gel/film formations
Flavourings and seasonings	Enhances taste

Adapted from Fiszman and Salvador (2003).

2.4.1 Flour and Starch

Wheat flour has been widely used as the base of batter due to its functional components. Wheat flour consists of 70-75% starch, 10-12% protein, 14% water and 2-3% non-starch polysaccharides (Goesaert et al. 2005). Wheat contains gluten which provides elasticity to the batter, allows coatings to expand during frying and aids in the movement of water and oil which results in a desirable texture (Mukprasirt et al. 2001). Hard wheat flour has higher gluten content than soft wheat flour, so it requires more water to generate the same consistency or viscosity. Soft wheat flour adheres better than hard wheat flour and provides a more tender texture (Hazen, 2005). Starch content in wheat flour also contributes to the final quality of fried products.

The major contents of starch are glucose polymers, namely amylose (linear), and amylopectin (branched). In the presence of water, starch granules swell and can hydrate up to 50% of their dry weight. In presence of heat, amylose leaches out of the starch granule which increases the viscosity of the system/batter. The heat-gelatinized starch determines the basic structure of the batter. Mohamed et al. (1998) reported that crispness is positively related to amylose content. They also pointed out that increased amount of water, amylopectin or excessive protein caused higher oil uptake and less crispy texture (1998). Rice starch and corn starch have a different size, shape than wheat starch, so levels to replace wheat starch must be adjusted. Corn starch based batters need continuous mixing in order to prevent solids from settling (Suderman, 1993). A greater proportion of rice flour was required to achieve the suitable viscosity because rice is a poor thickening agent (Shih & Daigle, 1999). Besides native flour and starches, there are also modified starches which provide a wide range of functionality to batters. Oxidized starches make batter sticky due to the bonding between its carboxyl group and protein in food substrate (Shinsato et al. 1999). Lenchin and Bell (1985) found that incorporating high amylose corn starch into batter resulted in par fried foods that were crispier and suitable for microwave cooking.

2.4.2 Gums

The primary use of gums in batter is to retain water and control viscosity which means improved adhesion between coatings and substrate. Gums increase viscosity of the batter and consequently reduce the number of problems associated with batter run-off. Gums aid in forming a film around the substrate which reduces the amount of fat absorbed during cooking and also reduces the amount of moisture migrating out (Brandt, 2002). Xanthan gum was identified as the best for improving adhesion in coated foods compared to guar gum and sodium carboxymethylcellulose (Hsia et al. 1992). The addition of gum in batter mix is very minimal (<1%); thus, it does not affect the functionality of other ingredients.

2.4.3 Leavening Agents

Depending on type of coating, leavening agents may or may not be used. The basic reaction that produces carbon dioxide is due to sodium bicarbonate and acids or acid salts. The timing of gas release must be controlled in order to obtain the desirable product and maintain quality which can be achieved by choosing certain acids. Some acids allow gas release at room temperature but some function at frying temperature.

Use of intermediate to slow acting leavening, mononcalcium phosphate monohydrate or sodium acid pyrophosphate, can delay the gas release caused by heat from mixing process (Loewe, 1990) and optimize texture and adhesion (Brandt, 2002).

2.5 Deep Frying

Deep fat frying is a cooking method which immerses foods in hot oil (~130 and 190°C) (Farkas, 1994). Deep fat frying involves structural changes on the surface and the inside of the substrate, as well as simultaneous heat and mass transfer resulting in opposite movement of water and oil (Bouchon et al. 2003). As shown in Figure 1, the cross-section of a food substrate during frying and image of the scanning electron microscope of fried potato crust illustrates the deep fat frying process. As described by Mellema, when food is immersed in hot oil, the water on exterior surface of food evaporates quickly and pores are formed which allows oil to flow into food to fill up the void (2003). As moisture is removed, surface of food is dried followed by rough structure formation. At the same time, heats moves inward to food, several physicochemical reactions (such as starch retrogradation, Maillard reactions and glass transitions) occur which are responsible for the unique colour, flavour and texture of fried products (Mellema, 2003). It is not fully understood how the oil enters into the food matrix, but evidence has shown that the majority of the oil is absorbed during the cooling period by capillary action and condensation. Gamble et al. (1987) suggested that oil was pulled into food by vacuum effect caused by steam condensation. Microscopic analysis of deep fried potato strips showed that oil only existed in the crust (Keller et al. 1986) and about 80% of the sponge-like crust's volume is made up of void space (Lima & Singh, 2001).

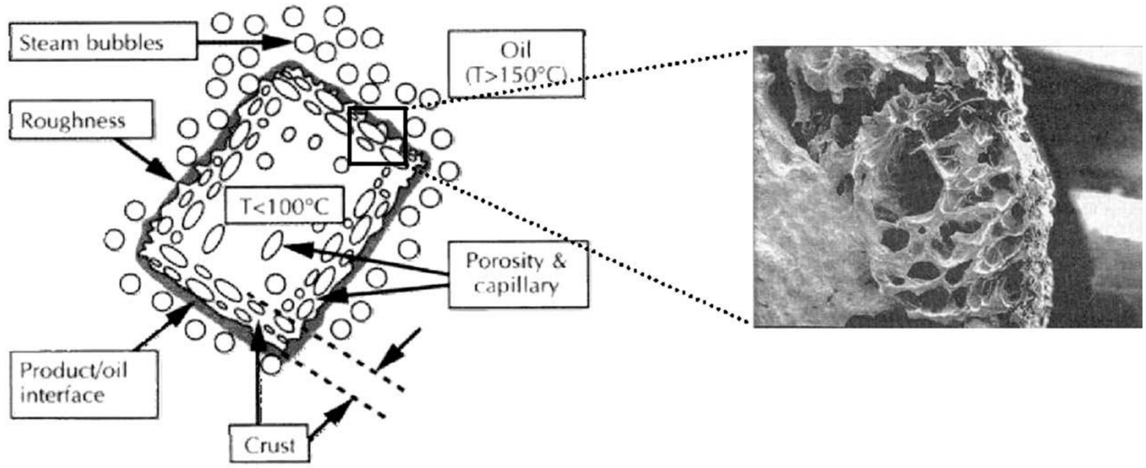


Figure 1: (left) Cross-section of a piece of food during deep fat frying from Saguy et al. (1998). (right) Scanning electron microscope image of cross-section of fried potato crust adapted from Singh, (1995).

3.0 FRENCH FRY

3.1 Market and Production

Potatoes are one of the major crops in the world. More than 30% of potatoes grown are utilized for French fry processing (Saguy & Pinthus, 1995). Driven largely by the growing popularity of Western style cuisine and quick service restaurants, billions of dollars in sales worldwide have been generated from frozen French fry and other potato products. The estimated global frozen potato production capacity is 9.6 million metric tonnes (mmt) per year. Over 90% of worldwide exports of potatoes were frozen French potato products, approximately 1.9 billion (Frozen Food Digest, 2002).

3.2 Processing

For commercial processing of French fries, steps include washing, weighing, peeling, trimming, sorting, cutting, grading into proper length and thickness, blanching, drying, frying, removal of excess fat, cooling, freezing and packaging (Lisinska & Leszczynski, 1989). Each step contributes to the final quality of the fry to a certain degree. Blanching is a key step in the process that inactivates enzymes which cause flavour, colour and texture degradation. Blanching also aids in retaining colour and texture and reducing oil pickup by gelatinizing the surface layer of starch. Moreover, removal of excessive sugar by blanching reduces browning reactions during frying. Generally, for better texture, two blanchers are used with low temperature (165°F) first, followed by blanching at 195°F (Gould, 1999). Pre-drying before frying plays a significant role in crispness and oil absorption. By pre-drying, oil pickup is reduced in two ways. Firstly, the open pore proportion is decreased by shrinkage; therefore, less oil enters into the pore. Secondly, frying time is shortened which reduces the time and amount of oil picked up. Frying is a two-step process, including par frying and final frying. The recommended frying temperature is from 130°C to 185°C (Lisinska & Leszczynski, 1989).

4.0 ONION RING

4.1 Market and Production

Onion rings are defined as a piece of onion, ring-shaped, coated with batter and/or breading and deep-fat fried before consumption. Coated onion rings are popular with consumers all over the world due to their unique texture and flavour. In 1988, **t**here were over 50 million pounds of batter or breader used for onion rings in U.S. (Hurni and Loewe, 1990).

4.2 Processing

Onion rings can be processed from either natural sliced or diced onion from an extruder. Natural sliced onion rings are made from onions that have been sliced but may have a high level of waste associated with them. Diced onion rings can be obtained from whole fresh onions, or scrap onions left from sliced onion ring process, or dehydrated dried onion which must be hydrated before use. Thus, onion rings made of diced onion not only reduce the waste and cost associated with processing, but also retain the shape, size and crispy texture. To produce onion rings from diced onions, all the onion pieces have to be mixed in a blender for 2 minutes with a matrix to form a mash. Typically the matrix contains sodium alginate, a heat setting starch source (flour or starch from wheat or corn) and flavouring agents. The ratio of onion to matrix is approximately 85:15. Additional water may be required to hydrate the onion before or after adding the matrix, based on the condition of the onion used. Commonly, onion rings made from diced onions are formed by an extruder (manufactured by DCA Food Industries, Inc.) which has a sliding metal cylinder that allows the mash to form a set-diameter and weight. During extrusion, dilute calcium chloride solution (5%) is used to direct the mash forming through the die. Calcium chloride reacts with sodium alginate in the mash to form a water-soluble gel; calcium alginate completely covers the onion ring and aids in releasing the onion ring at a high speed without breaking its shape.

Once the onion ring is obtained, coatings are ready to be applied. The coating for a sliced onion ring can be made up of a four or five step application: pre-dust-batter-breader-batter-breader. Pre-dusting is optional but is preferred when the substrate is wet. Pre-dust tends to increase the adhesion between first batter and substrate. Additional batter and bread steps provide full coverage to the coated food. Coatings for diced onion rings can be two steps (batter-breader) or three steps (batter-breader-batter). Pre-dust is not required in the application of batter onto onion rings as minimal problems as found in batter adhesion. After coating, onion rings are par fried at a temperature of 380-390°F for approximately 30 seconds, followed by freezing and packaging (Burge, 1983). Before consumption, a final frying step is required.

5.0 MOZZARELLA STICK

5.1 Market and Production

Mozzarella sticks are elongated breaded or battered cheese and deep-fat fried before consumption. They are the second most popular appetizer served in restaurants. The consumption of cheese sticks has increased 75% since 1980 with the majority of consumption (60%) from restaurants (McCain Food Service, 2011). Mozzarella sticks have a high profit margin with an estimated $4.24 profit per serving on average (McCain Food Service, 2011).

5.2 Processing

The most common cheese used for mozzarella sticks is low moisture, part skim mozzarella cheese. Mozzarella cheese with a high melting point is preferred in order to reduce the chances of blow-out during deep-fat frying. Mozzarella sticks appear in different sizes, flavours and fat and moisture levels. Commercially available, mozzarella sticks are battered and/or breaded and par fried.

The total coating pick-up for mozzarella sticks is approximately 45-60%. Four steps (batter-predust-batter-breader) or five steps (batter-predust-batter-predust-batter-breader) are required based on the batter thickness and target batter pick-up. Different hydration rates for batter may be applied. The first batter applied commonly has a higher hydration ratio (1 part of flour to 2 parts of water), whereas the second batter has a lower hydration ratio (1 part of flour to 1.6-1.8 parts of water) in order to obtain required batter pick-up. After the mozzarella stick is coated, it is par fried for 20 seconds at 380°F and frozen. To fully cook mozzarella stick, it requires deep fat frying for 2 minutes at 350°F before consumption. To avoid the cheese blowing out, the time and temperature used for frying must be carefully controlled.

6.0 QUALITY ASSESSMENT

Appearance, aroma, flavour and texture are major determinants in food quality. Meeting regulations and controlling production costs without compromising food quality is also essential to the food industry. The quality of fried foods is judged by processing efficiency (viscosity, batter pick-up, cooking yield) and sensory characteristics (colour, texture, sensory tests) and quality maintenance (freeze-thaw, heat lamp stability) via objective and subjective test methods.

6.1 Viscosity

Viscosity is one of the most critical factors determining batter behavior during frying (Loewe, 1990). Viscosity is a measurement of the resistance to flow and can be characterized as thick (high viscosity) or thin (low viscosity). If the batter is too thick, batter pick-up increases. If the batter is too thin, it has difficulty adhering to the food substrate. Viscosity can be measured by a Brookfield viscometer in centipoise. Viscosity is affected by temperature, mixing time and shear force applied; so in order to have a consistent quality, the parameters must be carefully controlled.

6.2 Coating Pick-up

Coating pick-up is the ratio of coating material picked up by the substrate. It is calculated by the formula outlined by Parinyasiri et al. (1991): coating pick-up=(coated weight-raw weight)/coated weight *100. The pre-dust, batter and/or breader pick-up can be calculated from this formula as well.

6.3 Cooking yield

Cooking yield is a good indicator of coating adhesion for fried food products. It should be tightly controlled for economic and quality reasons and to ensure coating level regulations are met. Cooking yield (%) is calculated as the coated product weight after frying/weight of the coated product before frying *100.

6.4 Colour

The desirable colour of a French fry should be light and golden without any browning or black spots (Lisinska & Leszczynski, 1989). The same colour concept is also true for onion rings and mozzarella sticks. Coating colour is determined by the cooking time, type of frying oil, oil absorption, coating thickness, level of corn ingredients and the availability of reducing sugars and proteins in food substrate. Colour can be characterized by colourimeter (HunterLAB or Minolta) using the L*a*b* colour system. The colour can also be evaluated compared to a colour chart for fried foods.

6.5 Texture: Crispness

Crispness is considered one of the most important attributes to consumers and processors. A good quality French fry has been described as having a crispy outer crust with mealy interior texture (Bouchon & Aguilera, 2001). The external layer of French fries should not be hard or leathery or gummy, whereas the interior should be similar to a baked potato. Deep-fat fried onion ring and mozzarella sticks should be crunchy.

Instrumentally, a texture analyzer has commonly been used to evaluate the crispness of coated food products. The number of fracture events and the force versus deformation curve has been proposed as an appropriate way to quantify crispness. In addition to mechanical tests, the sound emitted when a food sample is fractured is also a good indicator of crispness. Sanz et al. studied the effect of pre-frying and final frying times on the crispness of French fries by use of a texture analyzer (TA-XT Plus) with a aluminum probe (30° cutting angle, 15 mm wide) at a speed of 40 mm/second, as well the sound effect was detected by acoustic sensor (2007). According to Texture Technologies Corporation, firmness measurements on Shoestring French fries have been conducted using a TA.XT2 texture analyzer. Seven fries were placed on a guillotine holder and cut through by TA-42 Knife Probe with a 45° Chisel blade. This evaluation method has shown good precision and can be used to differentiate overall firmness of French fries (2005).

According to Ling et al. (1998), the texture of onion ring coating was measured by Instron Universal Testing Machine (Model TM, Instron Corp., Canton, MA) with a Kramer shear cell. Fried onion rings were cut into quarters and onion are pulled out to have intact coating. Each piece was weighed and placed in Kramer shear cell, and then force was applied until sample ruptured. Specific shear force in kN/kg can be calculated by the calculation: maximum load (kN)/ sample mass (kg).

Even though no research has been found done specifically on mozzarella stick, the texture analyzer could potentially used to evaluate the crispness of the breaded coating present on mozzarella sticks. In addition to objective measurement, the texture of mozzarella stick could also be rated by a trained sensory panel.

6.6 Freeze-thaw Stability

Commercially, all coated food products are par fried, stored in freezer and shipped out for distribution. Thus, it is necessary to see the stability of coated products after freezing and after temperature abuse that may occur during distribution. To evaluate, par fried samples are pulled out to thaw at room temperature, and once surface temperature reaches 4^{o}C, they are quickly frozen in a blast freezer (<-40^{o}C). After the surface temperature of samples drops to -18^{o}C, samples are removed from the blast freezer and stored in a regular freezer for at least 14 days. Samples are then cooked and colour, texture, oil loss and sensory analysis are assessed.

6.7 Heat-lamp Stability

Fried foods are usually held under a heat lamp in food service operations. Kuntz (1997) reported that heat lamp stability of fried food products (retaining a crispy coating over certain amount of time) is considered as a key coating characteristic. Physical changes were observed in deep-fat fried foods under a heat lamp over a period of time. Loss of crispness, moisture, overall quality and colour change may be observed. Oil migration from inside to coating surface may also occur with heat lamp exposure over time. Oil loss can be measured by weighing the amount of oil transfer to filter paper.

6.8 Sensory

Sensory evaluation is an important tool in food product development which provides valuable feedback on acceptability or quality of foods. The flavour, aroma and touch are difficult to be imitated instrumentally. Appearance, aroma, texture and flavour can be evaluated subjectively. In the case of coated food products, colour, crispness, moistness, greasiness, tenderness, flavour and overall quality are the key attributes to be assessed. Coated food colour charts can be used as reference. Sensory evaluation should be conducted at least 8 to 10 trained panellists. Samples should be given to panellists in a random order. Line or hedonic scales are commonly utilized.

7.0 COMMON PROCESSING PROBLEMS

There are several problems that can be encountered in coating food substrates including insufficient/excess coating pick-up, uneven coating, batter tails and shoulders, dark and/or uneven colouration, ballooning, inadequate leavening of tempura batters, reticulation (surface drying or lacing) of tempura batters and shelling (Barbut, 2002; Sansiela, 1990). Insufficient or excessive coating pick-up typically results from improper batter viscosity, temperature or improper conveyor belt speed. These parameters should be monitored on a regular basis. Uneven top or bottom coating, or a bare spot on a product without coating (breading void), could be due to a number of factors including uneven batter disposition or partially frozen and/or oily substrate surfaces. Also, conveyor belt speed or inadequate transfer between machines may cause disruption and destroy coating integrity. Furthermore, inadequately leavened batter can be caused by thin batter viscosity, high mixing speeds and /or high holding temperature.

Tail and shoulder batter defects are caused when excessive batter adheres to product ends. It may be a result of excessively thick batter, or that the blow-off device is not set at high enough pressure to remove excessive batter.

Dark colour occurs from high frying temperature, long frying time or excessive amounts of reducing sugars in the formulation. Non-uniform colouration may result from improper mixing pre-dust which contains colouring agents and/or incomplete batter coverage around food substrate.

The ballooning defect is the separation of coating from the substrate after frying and leads to the coating falling off. It is caused by air bubbles formed by water vapor evaporation that were unable to escape because they were trapped between the substrate and coating. It can be controlled by adjusting the formulation by increasing the percentage of ingredients with a finer particle size which could create a more porous layer and aid in water evaporation. The addition of gum also could modify the porosity of coating.

Reticulation or surface drying is a common coating defect which can be remedied by spraying with water mist after freezing.

Shelling is often seen in tempura style batters with inadequate puffing and porosity or if the temperature of the substrate is too low during the pre-dust step. In addition, it may occur if too much time elapses between battering and par frying as an excessive amount of gas may be liberated. Thus, processing parameters must be tightly controlled to ensure a consistent, high quality product is produced.

8.0 PEA INGREDIENTS

Isolation of pea fractions from the whole pea is difficult due to the presence of insoluble protein and fine fibre. Pea fractions (flour, starch, protein, fibre) can be obtained by either dry or wet milling. Best Cooking Pulses and Nutri-Pea Ltd. (Manitoba) and Parrheim Foods (Saskatchewan) are major processing companies that produce pea fractions. A large range of pea varieties are processed by these companies, such as Midas, Eclipse and Golden. The specific variety used for fractionation may vary from year to year and depends on local availability. In addition, different processing techniques are employed by the two dry milling companies which could affect performance of pea ingredients. Substitution of traditional corn or wheat ingredients in coating formulations by pea fractions may result in different batter viscosity, coating pick-up and the quality of finished products.

8.1 Pea Starch

Pea starch has excellent gel-forming properties. When pea starch is used at 3% solution, a soft gel is formed and at 5%, a firm gel is formed. In this study, the two starches used are “Accu-Gel™” from Nutri-Pea Ltd. and “Starlite™” from Parrheim Foods. Both are classified as native starch. “Accu-Gel™” is isolated using wet milling techniques, whereas “Starlite™” is obtained by dry milling. Based on different milling techniques, “Accu-Gel™” is a purer starch (>95%) than “Starlite” (84%). Both starches contain high levels of amylose (~ 5%). Both starches have a bland flavour and a lighter colour which allow them to be incorporated into batters without changing the quality profiles of finished products.

8.2 Pea Flours

Whole pea flours are obtained by grinding the entire pea; whereas, split pea flours are obtained from the endosperm of the pea. Nutritionally, pea flours differ from wheat flour in a number of aspects. Pea flour contains 22-25% of protein, whereas wheat flour contains 10-12% protein. Pea flour contains 2.5% ash and wheat flour contains 0.4%. Pea flour also has much more total dietary fibre (11-14%) than wheat flour (2.6%).

As indicated by Sosulski & McCurdy (1987), field pea fractions (flour & protein) have good water holding and oil absorption capacity which suggest that they have potential for use as fillers, binders and extenders in meat emulsion systems and bakery products. Petitot et al. (2010) reported that substitution with 35% split pea flour in pasta increased hardness and elasticity due to its higher protein content and lower water uptake. Increased fracturability and reduced brightness was also observed in the pasta due to the presence of high levels of ash in pea flours (Petitot et al. 2010). Repetsky & Klein reported that replacement of wheat flour (2.5%, 5% and 10%) with pea flour did not affect proofing time and bread volume; whereas, 10% replacement lowered the quality (flavour, texture and colour) of bread (1981).

Commercially available pea flours include Parrheim Foods split pea flour (Fiesta™), Best Cooking Pulses (BCP) yellow split pea flour and BCP yellow whole pea flour. Split pea flours can be used in food applications such as extruded snacks, batters and breadings, baked goods and sauces. Compared to split pea flour; whole pea flour contains more fibre due to the presence of hull.

8.3 Pea Fibre

Dietary fibre is defined by American Association of Cereal Chemists as "the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine (AACC, 2001). It is believed that dietary fibre can help lower cholesterol and control blood glucose levels. Peas contain 14-26% of total dietary fibre: 10-15% insoluble fibre and 2-9% soluble fibre (Tosh & Yada, 2010). Pea fibre consists as inner (cotyledon fibre, consist of cell wall polysaccharides) or outer fibre (seed coat or hull fibre). There are a variety of pea fibres commercially available. Nutri-Pea manufactures a line of pea hull fibres; Centara 3, Centara 4, Centara 5 and Uptake 80. Uptake 80 is a functional fibre that contains starch and protein in addition to soluble and insoluble pea fibre. BCP and Parrheim Foods each process a hull fibre, Best and Exlite, respectively.

Research on pea fibre has focused on the functionality of pea fibre, as well as its nutritive value. There is an increasing interest in the incorporation of pea fibre into baked goods, bread and pasta. Pea fibre has been shown to have good fat binding properties in high-fat beef patties. Texture enhancement in low-fat sausages, beef-patties and minced fish was also observed after addition of pea fibre. Ang et al. (1991) reported that a high quality product was produced by adding pea fibre at level of approximately 0.3-3% by weight of batter. Pea fibre was noted for enhancing appearance and strengthening the batter to allow it to remain intact during processing and help in water retention (Ang et al. 1991).

9.0 REFERENCES

AACC (2001). The definition of dietary fibre, *Cereal Foods World, 46*: 112-126.

Agriculture & Agri-Food Canada (2010). Overview of the Canadian Pulse Industry 2009. Retrieved on Feb 16, 2011, from http://www.ats-sea.agr.gc.ca/can/4753-eng.htm.

Ang, T., Miller, W., & Blais, I. (1991). Fibre additive for frying batters, US Patent 5019406. Retrieved on Feb 24, 2011, from http://www.patentstorm.us/patents/5019406/fulltext.html.

Barbut, S. (Ed.) (2002). Battering and breading. In *Poultry products processing* (pp. 289 314). New York: CRC.

Bouchon, P. & Aguilera, J.M. (2001). Microstructural analysis of frying potatoes, *International Journal of Food Science and Technology, 36*: 669-676.

Bouchon, P., Aguilera, J.M., & Pyle, D.L. (2003). Structure oil absorption relationships during deep-fat frying, *Journal of Food Science, 68*: 2711-2716.

Brandt, L. (2002). Sticky business: Creating coatings that stick, *Prepared Foods.* Retrieved on Dec 20, 2010, from http://findarticles.com/p/articles/mi m3289/is 9171/.

Burge, M.R. (1983). Application to onion rings and other vegetables. In R.D. Suderman & E.F. Cunningham (Eds.) *Batter and Breading Technology* (pp.76-89). Connecticut: AVI.

Canadian Celiac Disease Association (2011). Celiac Disease. Retrieved on Feb 17, 2011, from http://www.celiac.ca/EnglishCCA/eceliac.html.

Chibbar, N.R., Ambigaipalan, P. & Hoover, R. (2010). Molecular diversity in pulse seed starch and complex carbohydrates and its role in human nutrition and health, *Cereal Chemistry, 87*: 342-352.

Cunningham,F.E., & Suderman, D.R . (1981). Use of batters and breadings on food products: A review, *Proceedings of the 5th European Symposium,* May 17-23, Apeldoorn, NL.

Farkas, B.E. (1994). Modeling immersion frying as a moving boundary problem. *Ph.D. dissertation*, University of California, Davis.

Fiszman, M. S. (2009). Coating Ingredients. In R. Tarte (Eds*.) Ingredients in Meat Products. Functionality and Applications* (pp.253-289). Philadelphia: Springer Science + Business Media, LLC.

Fiszman, M.S., & Salvador, A. (2003). Recent Development in coating batters, *Trends in Food Science & Technology, 14*: 399-407.

Frozen Food Digest (2002). French fries driving globalization of frozen potato industry. Retrieved on Feb 15, 2011, from http://findarticles.com/p/articles/mi_hb6641/is_2_18/ai_n28965693/.

Gamble, M.H., Rice, P., & Selman, J.D. (1987). Relationship between oil uptake and moisture loss during frying of potato slices from CV record UK tubers, International *Journal of Food Science and Technology, 22*: 233-241.

Goesaert, H., Brijs, K., Veraverbeke, S.W.,Courtin, M.C., Gebruers, K., & Delcour, A,J. (2005). Wheat flour constituents: how they impact bread quality, and how to impact their functionality, *Trends in Food Science & Technology, 16*: 12-30.

Gould, A.W. (Ed.) (1999). Frozen French fries and other frozen potato products. In *Potato Production, Processing and Technology* (pp. 105-111). Maryland: CTI.

Han, J. & Tyler, R. (2003). Characterization of pea starches in the presence of alkali and borax, *Starch, 55*: 457-463.

Hazen, C. (2005). Getting the better of batter and breading, *Food Product Design, 15*: 32-55.

Hsia, H.Y., Smith, D.M., & Steffe, J.F. (1992). Rheological properties and adhesion characteristics of flour-based batters for chicken nuggets as affected by three hydrocolloids*, Journal of Food Science, 57*: 16-18, 24. http://www.freepatentsonline.com/5019406.html.

Hurni, R. J. & Loewe, R. (1990). Batters and breadings: The present and future market. In K. Kulp & R. Loewe (Eds.) *Batters and Breadings in Food Processing* (pp. 1-10). St. Paul: AACC.

Keller, C., Escher,F. & Solms, J. (1986). A method for localizing fat distribution in deep-fat fried potato products, *Food Science Technology, 19*: 346-348.

Kuntz, L. (1997). The great cover-up: Batters, breadings, and coatings, *Food Product Design*. Retrieved on Feb 15, 2011, from http://www.foodproductdesign.com/articles/ 1997/04/the-great-cover-up-batters breadings-and-coatin.aspx.

Lenchin, J.M., & Bell, H. (1985). Process for coating foodstuff with batter containing high amylose flour for microwave cooking, *US patent 4,529,607*.

Lima, I. & Singh, P.R. (2001). Viscoelastic behavior of fried potato crust, *Journal of Texture Studies*, 32: 131-141.

Ling, Du., Gennadios, A., Hanna, A.M., & Cuppett, L.S. (1998). Quality evaluation of deep-fat fried onion rings, *Journal of Food Quality, 21*: 95-105.

Lisinska, G., & Leszczynski, W. (Ed.) (1989). Potato chips and French fries. Potato Science and Technology (pp. 166-227). England: Elsevier Science.

Loewe, R. (1990). Ingredient selection for batter systems. In K. Kulp & R. Loewe (Eds.) *Batter & Breadings in Food Processing* (pp. 11-28). St. Paul: AACC.

Makinson, J. H., Greenfield, H., Wong, M.L., & Wills, R.B.H. (1987). Fat uptake during deep fat frying of coated and uncoated foods, *Journal of Food Composition & Analysis, 1*: 93.

McCain Food Service (2011). Why appetizers? Retrieved on Feb 28, 2011, from http://www.mccainusa.com/mccainfoodservice/solutioncenter/whyAppetizers.aspx.

Mellema, M. (2003). Mechanism and reduction of fat uptake in deep-fat fried foods, *Trends in Food Science and Technology, 14*: 364-373.

Mohamed, S., Hamid, A. N., & Hamid, A. M. (1998). Food components affecting the oil absorption and crispness of fried batter, *Journal of Science Food & Agriculture, 78*: 39-45.

Mukprasirt, A., Herald, T. J., Boyle, D. L., & Boyle, E.A.E. (2001). Physicochemical and microbiological properties of selected rice flour-based batters for fried chicken drumsticks. *Poultry Science, 80*: 988-996.

Packaged Facts (2009). Functional foods and development in the United States, Retrieved on December 14, 2011 from https://www.packagedfacts.com/functional-foods-beverages

Packaged Facts (200). The gluten-free food and beverage market, Retrieved on December 14, 2011 from https://www.packagedfacts.com/gluten-free-food

Parinyasiri, T., Chen, T., & Reed, R. (1991). Yields and breading dispersion of chicken nuggets during deep-fat frying as affected by protein content of breading flour, *Journal of Food Processing and Preservation, 15*: 369-376.

Petitot, M., Boyer, L., Minier, C., & Micard, V. (2010). Fortification of pasta with split pea and faba bean flours : pasta processing and quality evaluation, *Food Research International, 43*: 634-641.

Repetsky, A.J. & Klein, P.B. (1981). Partial replacement of wheat flour with yellow field pea flour in white pan bread. *Journal of Food Science, 47*: 326-327.

Saguy, I.S., & Pinthus, E.J. (1995). Oil uptake during deep fat frying: Factors and mechanisms. *Food Technology, 49*: 142-145.

Saguy, I.S., Ufheil, G., & Livings, S. (1998). Oil uptake in deep-fat frying: Review, *Ocl Oleagineux Corps Gras Lipides, 5*: 30-35.

Sanz, T., Primo-Martin, C., & Vliet, V. T. (2006). Characterization of crispness of French fries by fracture and acoustic measurements, effect of pre-frying and final frying times, *Food Research International, 40*: 63-70.

Sasiela, R.J. (1990). Troubleshooting techniques for batter and breading systems. In K. Kulp and R. Loewe (Eds.) *Batters & Breadings in Food Processing* (pp. 227-244). St. Paul: AACC.

Saskatchewan Agriculture and Food. (2001). Market analysis consumer-ready pulse products, Retrieved on Feb. 14, 2011, from http://www.agriculture.gov.sk.ca/Default.aspx?DN=af89533f-2a6e-4d44-a9929b100040a7aa.

Shih, F. & Daigle, K. (1999). Oil uptake properties of fried batters from rice flour, *Journal of Agriculture and Food Chemistry, 47*: 1611-1615.

Shinsato,E., Hippleheuser, A.L., & Van Beirendonck, K. (1999). Products for batter and coating systems*, The World of Ingredients, 1*: 38-42.

Shukla, T. P. (1993). Batters and breadings for traditional and microwavable foods, *Cereal Foods World, 38*: 701-702.

Singh, R.R. (1995). Heat and mass-transfer in foods during deep-fat frying*, Food Techonology, 49*: 134-137.

Sosulski, W.F. & McCurdy, R.A. (1987). Functionality of flours, protein fractions and isolates from field peas and faba bean, *Journal of Food Science, 52*: 1010-1014.

Suderman, D.R. (1993). Selecting flavouring and seasonings for batter and dreading Systems, *Cereal Foods World, 38*: 689-694.

Texture Technologies Corporation. (2005). TA.XT2 Texture Application Study: Shoestring French Fries, Personal communication.

Tosh, M.S. & Yada, S. (2010). Dietary fibres in pulse seeds and fractions: Characterization, functional attributes, and applications, *Food Research International*, *43*: 450-460.

Yang, C.S. & Chen, T.C. (1979). Yield of deep-fat fried chicken parts as affected by preparation, frying conditions, and shortening, *Journal of Food Science, 44*: 1074-1092.

APPENDIX B: FRENCH FRY SENSORY BALLOT

Sensory Ballot---French Fries   Time: _______   Name: _____________   Date: ____________

No rating between anchors on lines is allowed. Please record your results in the table.

1. Colour: visual rating of the coating colour intensity compared to Colour Standards for Frozen French Fried Potatoes**.**

a) 00   b) 0   c) 0.5   d) 1   e) 1.5   f) 2   g) 3

2. Surface texture: The appearance of outside coating is:

1) very rough   2) moderately rough   3) slightly rough   4) smooth

<u>Bite in the middle of French fry, and rate the following criteria.</u>

3. Exterior bite: how easily French fries break when bitten with your front teeth; easy to bite through =tender ; difficult to bite through=tough

Tender				Tough/Leathery			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
extremely	very	moderately	slightly	slightly	moderately	very	extremely

4. Crispness: force and noise with which the French fry breaks or fractures when chewed with your front & molar teeth

Soggy				Crispy			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
extremely	very	moderately	slightly	slightly	moderately	very	extremely

5. Overall moistness of French fry is

Dry					Moist			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
extremely	very	moderately	slightly		slightly	moderately	very	extremely

6. Baked potato flavour: how much baked potato flavour you have

1) none   2) slight   3) moderate   4) extreme

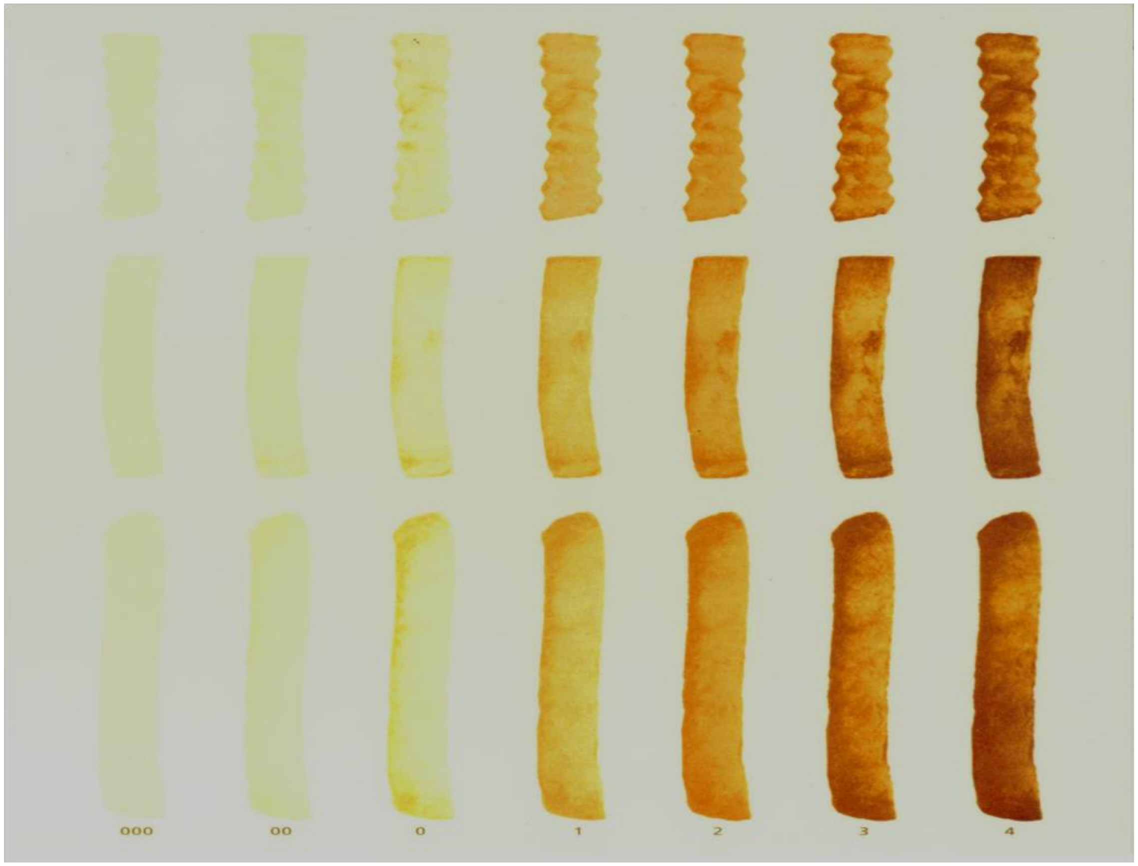
7. Off flavour

1) none   2) slight   3) moderate   4) extreme

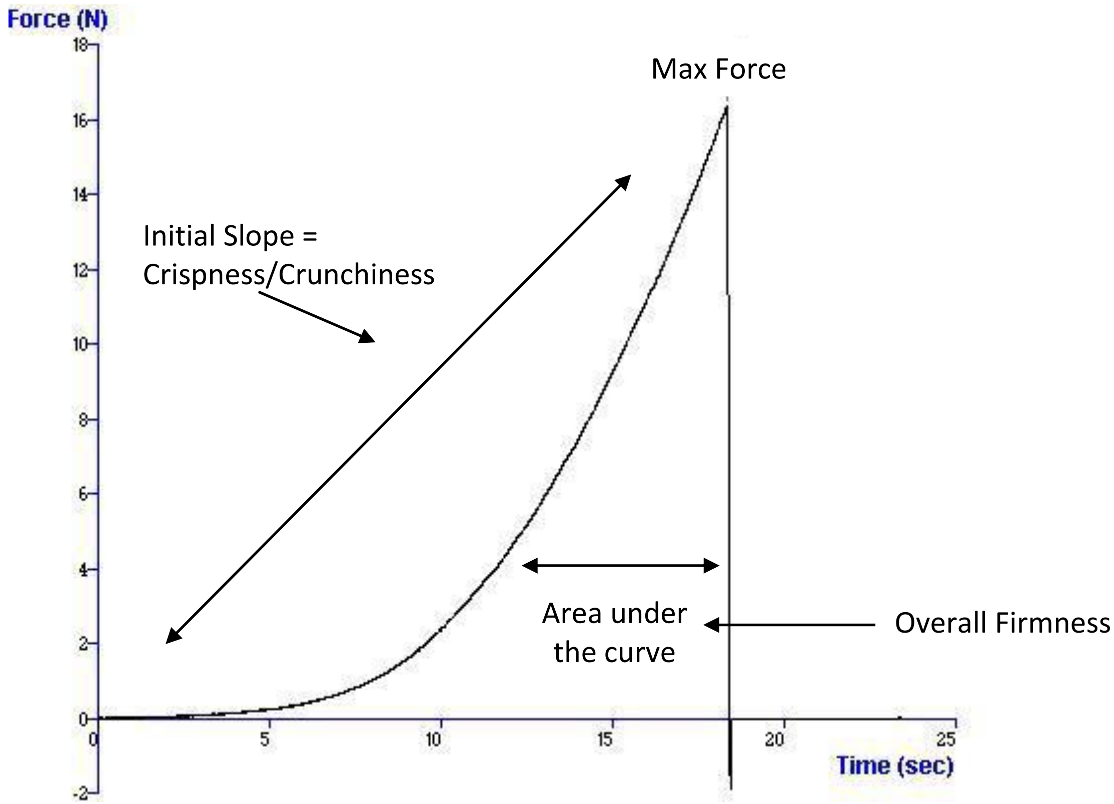
8. Overall quality is

Low				High			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
extremely	very	moderately	slightly	slightly	moderately	very	extremely

APPENDIX C: UNITED STATES DEPARTMENT OF AGRICULTURE COLOUR STANDARDS FOR FROZEN FRENCH FRIED POTATOES



APPENDIX D: A TYPICAL CURVE GENERATED BY TA-XT2 TEXTURE ANALYZER



Attachment: TA-42 Knife probe (45 chisel blade)

Mode: Cut test to determine overall firmness and crispness/crunchiness of coatings

Pre-test Speed: 2mm/sec

Test Speed: 1mm/sec

Post-test Speed: 2mm/sec

Resistance: 5g

Distance: 9mm

Load Cell: 25kg

APPENDIX E: MOZZARELLA STICK SENSORY BALLOT

Sensory Ballot---Mozzarella sticks Name: _________ Date: _________ Time: ________

❖ No half point rating is allowed. Please record your results in the table.

1. Colour: visual rating of the coating colour intensity compared to Flour Breader Fry Colour Chart.
1) 1 2) 2 3) 3 4) 4 5) 5 6) 6

<u>Bite a sample's coating with your teeth and rate the following criteria.</u>

2. Crispness: force and noise with which the sample breaks or fractures when chewed with your front teeth (first and second chew). (Crispy = noisy at biting, light and flaky)
1) Not crispy 2) slightly crispy 3) moderately crispy 4) very crispy

3. Crunchiness/ hardness: force required to compress sample between your molar teeth
1) Not crunchy 2) slightly crunchy 3) moderately crunchy 4) extremely crunchy

4. The texture of cheese inside is
1) Very firm 2) firm 3) melted/Soft 4) very melted/soft

5. The degree of beany flavour detected?
1) none 2) slight 3) moderate 4) extreme

6. Overall quality is

Low				High		
1	**2**	**3**	**4**	**5**	**6**	**7**
extremely	very	moderately	board line	moderately	very	extremely

Sample ID				
1	**Colour**			
2	**Crispness**			
3	**Crunchiness**			
4	**Cheese texture**			
5	**Flavour**			
6	**Overall quality**			

COMMENT

Please comment on aroma, greasiness and cheese flavour if you notice any differences among samples. Thank you!

APPENDIX F: NEWLY WEDS FLOUR BREADER FRY COLOUR CHART

APPENDIX G: ONION RING BALLOT

Sensory Ballot---Onion Rings Name: _________ Date: _________ Time: ________

- ❖ No half point rating is allowed. Please record your results in the table.

1. Colour: visual rating of the coating colour intensity compared to Flour Breader Fry Colour Chart.

1) 1 2) 2 3) 3 4) 4 5) 5 6) 6

Remove the onion from the coating and bite the sample's coating and rate the sample for the following attributes.

2. Crispness: force and noise with which the sample breaks or fractures when chewed with your front teeth.

1) Not crispy 2) Slightly crispy 3) Moderately crispy 4) Extremely crispy

3. Crunchiness/ hardness: force required to compress sample between your molar teeth.

1) Not crunchy 2) Slightly crunchy 3) Moderately crunchy 4) Extremely crunchy

Bite the sample (coating & onion) and rate the samples for the following attributes.

4. The degree of beany flavour detected?

1) None 2) Slight 3) Moderate 4) Extreme

5. Overall quality is:

Low				High		
1	**2**	**3**	**4**	**5**	**6**	**7**
extremely	very	moderately	border line	moderately	very	extremely

Sample ID				
1	Colour			
2	Crispness			
3	Crunchiness			
4	Flavour			
5	Overall quality			

COMMENTS

Please comment if you notice any notable differences among samples (ie. aroma, greasiness, and flavour). Thank you