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Pulse Canada and Saskatchewan Pulse Growers

PERFORMANCE OF LENTIL FLOUR AS A BATTER AND BREADING AGENT FOR FRIED CHICKEN, FISH AND POTATO PRODUCTS

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Project Overview

Saskatchewan Pulse Growers, in collaboration with Pulse Canada, is requesting data to assess the performance of lentil flour as a batter, breading or coating agent under simulated foodservice conditions. The overall goal of this study is to generate scientifically backed evidence that will speak to the benefits of incorporating lentil flour in these applications. The results of this study will be used as part of ongoing outreach initiatives to encourage adoption of lentil ingredients in the US foodservice industry.

The Canadian pulse industry has set a '25 by 2025' target for achieving incremental use of 25% of pulse production (2 million tonnes) in non-traditional markets or end-use applications by 2025. Pulse specific strategies were developed to meet the 2 million tonne target based on current production levels in Canada, available ingredient formats, processing capacity and projected growth. The strategy for lentils is focused on directing an incremental volume of 625,000 tonnes to new markets through increased processing into flours and fractions as well as whole lentil consumption in the US foodservice market. Recent inquiries by stakeholders have indicated that there may be opportunities to apply for lentil flour in the foodservice market as a batter, breading and/or coating agent. Given the cost of lentil relative to competing ingredients, successful adoption within this market will be required to demonstrate a significant benefit to the manufacturer. However, there exists little scientific evidence to highlight the benefit of lentil flour in this particular application. The goal of this study is therefore to assess the performance of lentil flour as a pre-dust, batter and breading agent in food applications while:

- Simulating foodservice operating conditions,
- highlighting the benefits or successes of lentil performance versus competing ingredients, and
- identifying relationships between lentil flour physicochemical composition and performance.

Objectives

- **Phase 1: Physico-chemical testing of lentil flours (treated and untreated)**
- **Phase 2: Preliminary testing and ingredient functionality**
  - **Breading composition**
  - **Breading pickup**
  - **Par fry yield**
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  - **Sensory evaluation**
  - **Instrumental color analysis**
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- **Phase 3: Formulation optimization and quality assessment**
  - **Fried chicken – bone in thighs and boneless fillets**
  - **Fried potatoes - Fries**
  - **Fried Fish – Battered Haddock**

Summary

The Prairie Research Kitchen tested the effects of both a treated and untreated lentil flour inclusion in various breaded coating systems including bone-in chicken thighs, chicken fillet tenders, fish fillet and potato French fries. In preliminary trials, lentil flours were tested at 10% inclusion intervals in the breading component of a 3-part system in bone-in chicken thighs to determine a range to evaluate the effects of lentil flour inclusion on the quality of a breading system. After evaluation, the effects of lentil flours at 20, 30 and 40% inclusion of the breading coating system was selected for further testing. Lentil flour inclusions greater than 40% effected eating quality of the chicken with respect to mouthfeel (dry, powdery, starchy, brittle) and flavour (burned, scorched, dark brown).

Based on the cumulative quality of bone in chicken thighs with emphasis on colour development, flavour and texture acceptability the use of 30% untreated lentil flour was selected for continued optimization trials due to its colour characteristics, flavour profile and holding capability under heat lamp as well as to maximize the amount of lentil flour that could be successfully included in the formulation.

Colour development, texture and holding properties were also considered as key high value attributes of the inclusion of lentil flour in chicken tender coating system formulations and 40% treated lentil flour was selected for further optimization trials of the chicken tenders. Optimized breaded bone-in chicken thighs and chicken tenders were compared for quality against commercial samples.

Battered fish fillets and coated French fried were also assessed as optimized products using the 40% treated lentil flour within the coating system. This was seen as the maximum inclusion level of the lentil flour in the systems without making alterations to the formulations to include more functional ingredients.

Materials and Methods

Lentil flour: Treated and untreated red lentil flours were sourced from AGT Foods (Saskatoon Saskatchewan). Flours were analyzed for their physico-chemical and functional properties. Testing included moisture content (%, vacuum oven method AOAC: 945.43*, 934.01 Medallion Labs, Minneapolis Minnesota), starch content (%, AOAC 979.10*, AACC 76-11* Medallion Labs, Minneapolis Minnesota), amylose (%, Megazyme K-AMYL 07/11 Medallion Labs, Minneapolis Minnesota), amylopectin (%, Medallion Labs, Minneapolis Minnesota), total dietary fibre (%, AOAC 991.43 Medallion Labs, Minneapolis Minnesota), soluble fibre (%, Medallion Labs, Minneapolis Minnesota), insoluble fibre (%, Medallion Labs, Minneapolis Minnesota), protein (%, AACC 46-30*; AOAC 992.15* Medallion Labs, Minneapolis Minnesota), water holding capacity (g water/g flour, Prairie Research Kitchen), oil holding capacity (g oil/g flour, Prairie Research Kitchen), particle size distribution sieve analysis (µm, screen analysis, Prairie Research Kitchen) and differential scanning calorimetry (onset temperature °C, enthalpy (normalized, J/g) and peak temperature °C Medallion Labs, Minneapolis Minnesota). Flour testing was analyzed in duplicate and reported as the average ± standard deviation unless otherwise indicated.

* Method modified

Newly Weds control breading system: The control breading system was selected by the client and sourced from Newly Weds Foods. The breading system consisted of a spice mix (S18553-X1) and breader (A51252-X1). The control breading system applied to the products was blended by weight and consisted of 25% spice mix and 75% breader.

Lentil breading system: Treated (T) and untreated (UT) lentil flours were blended into the 75% breader component of the breading system at inclusions of 20%, 30% and 40% based on preliminary assessment of effective inclusion levels (results not shown in this report). Breading systems were coded as follows T20, T30 T40, UT20, UT30, UT40.

Chicken Products: Raw chicken ingredients were sourced from Dunn Rite Poultry (Winnipeg, Manitoba). Chicken products assessed in this study included bone in back off chicken thighs and boneless chicken fillets.

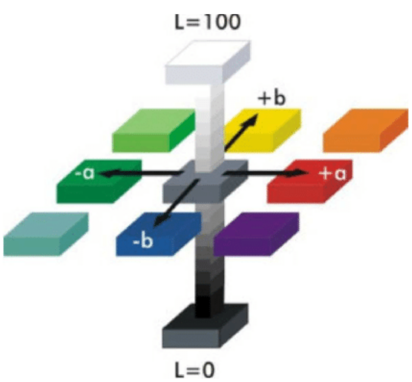
Potato - French Fries: French fries were produced from russet potatoes (Easterday Farms, Pasco Washington, USA). Fries were produced at the Prairie Research Kitchen with a French fry press fixed with a 0.7 cm cube blade. Raw cut potatoes were steamed in a Rationale oven for 4mins, dried at 30°C for 5 min, cooled to 5°C. Cooled fries were then battered and blanched in 350°F oil for 45 seconds and frozen. Frozen fries were cooked at 350°F for 2 minutes and 30 seconds. For optimization trials, French fries were coated with a batter consisting of 30g of T40 breading and 70g water.

Fish Fillet: High Liner IQF Haddock loins were used in the preliminary work to assess batter coating. For optimization trials, loins were dredged in a batter consisting of 50g of T40 breading, 0.8g baking powder and 125g sparkling water.

Commercial Controls: Optimized chicken products were compared to commercial controls including bone in fried chicken from Kentucky Fried Chicken (Original Recipe) and Popeyes (Mild Signature) retail locations in Winnipeg, MB.

Analytical Methods

Color: All products were assessed for color based on L* a* and b* values measured in duplicate using a Konica Minolta CR-10 Plus Color Reader. Delta E (ΔE) values were calculated to demonstrate differences in colour perceptibility between samples.



≤ 1.0: Not perceptible by the human eye
1-2: Perceptible through close observation
<2-10: Perceptible at a glance
11-49: Colors are more similar than the opposite
100: Colors are exactly the opposite
https://www.viewsonic.com/library/creative-work/what-is-delta-e-and-why-is-it-important-for-color-accuracy/

Moisture: Moisture analysis was performed on 2g samples of fried chicken skin and coating using a Metler Toledo HE73 moisture analyzer. Chicken tenders were prepared for moisture analysis by AOAC method 983.18 and dried using a Metler Toledo HE73 moisture analyzer.

Fat: Fat analysis was performed on the fried chicken skin and coating removed from the cooked chicken thighs. Fat samples for fried chicken tenders were taken from the blended chicken tenders mixture prepared during moisture analysis. Fat samples for both chicken products were sent to Medallion Labs (Minneapolis, Minnesota) and analyzed by gravimetric method.

Texture: A CT3 texture analyzer (Brookfield Ametek) was used to assess the change in cooked texture of both the fried chicken thighs and tenders held for one hour in clamshell take out containers and under a heat lamp at 50°C. The texture of the fried chicken thighs was assessed using a TA9-Needle probe (1.00mm D, 43 mm L) with a target distance of 5 mm, trigger load of 5.0g and test speed of 0.50 mm/s. The needle probe was used to assess the force required to puncture the skin of chicken with out puncturing the meat.

The texture of fried chicken tenders was assessed using a TA7 Knife edge probe (60mm W) a target value of 10 mm, trigger load of 5.0 g and a test speed of 10 mm/s. The center of the tenders were sampled at 1 inch widths and thicknesses greater than 1 cm.

Differential Scanning Calorimetry: Samples were sent to Medallion Labs (Minneapolis, Minnesota) for DSC analysis. Samples were run in a stainless steel pan with approximately 10mg of sample and 20mg of water, on a TA DSC2500 by the following profile. Enthalpy values were corrected for moisture.

1. Ramp 40 °C/min to 0.00 °C
2. Isothermal 2.0 min
3. Ramp 10 °C/min to 200.00 °C

Research Results and Discussion

Phase 1- Flour Functionality

Both treated and untreated red lentil flours were analyzed for their composition, physical and functional properties. Results are presented in Table 1.

The compositional characteristics between the treated and untreated lentil flours were quite similar with only minor differences in moisture content and protein content of the flour samples.

With respect to functional properties of the flours, the treated red lentil flour had considerably higher water absorption capacity compared to the untreated lentil flour which could potentially be due to increased starch damage, reduced moisture level and greater affinity for gelatinized starches to imbibe water. Water absorption properties relate directly to performance of ingredients and may be related to differences in performance between the treated and untreated flours in breading coating applications.

Oil holding capacity between the two flours was also reported as a difference between treated and untreated samples. This attribute is likely related to difference in fat content of the finished fried samples.

Particle size distribution between the samples was also quite different with the treated lentil flour having a much finer overall granulation compared to the untreated red lentil flour. Particle analysis testing was also hindered in the treated lentil flour. The treated flours had an agglomerating characteristic making sieve analysis of the samples quite difficult and skewing results to appear that the flour is coarser than it is (especially in the > 100 micron range). This may possibly be due to the fine grinding of these flours producing damaged starches as well as the partial gelatinization of starches increasing the stickiness of the flours.

Differential Scanning Calorimetry tests were used to assess the enthalpy of reactions in the samples. Differences in the enthalpy between samples is attributed to the starch gelatinization in the samples and untreated samples undergo gelatinization within the test while treated samples which have already undergone partial gelatinization do not carry the same reaction enthalpy (DSC curves can be found in Appendix A).

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Table 1: Properties of treated and untreated red lentil flour

Flour Properties	Treated Lentil Flour	Untreated Lentil Flour
Composition		
Moisture[b], %	6.24	8.36
Starch Content, %	52.35 ± 0.49	53.15 ± 0.35
Amylose (% of total starch)	28.04 ± 0.73	27.23 ± 0.08
Amylopectin (% of total starch)	71.97 ± 0.73	72.78 ± 0.08
Total Dietary Fibre	9.05 ± 0.07	8.45 ± 0.21
Insoluble Dietary Fibre, %	6.55 ± 0.07	5.90 ± 0
Soluble Dietary Fibre, %	2.50 ± 0	2.55 ± 0.21
Protein, % (6.25 conversion factor)	25.65 ± 0.07	24.80 ± 0
Functional Properties		
Water Holding Capacity, g/g	1.93 ± 0.02	0.75 ± 0.03
Oil Holding Capacity, g/g	0.66 ± 0.01	0.71 ± 0.01
Physical Properties		
Particle Size Distribution[b] (%)		
>600 µm	0.8	1.12
450 – 600 µm	0.9	0.88
250- 450 µm	4.2	1.75
150 – 250 µm	6.7	8.70
100 - 150 µm	22.6	29.28
75 – 100 µm	25.9	26.23
45 – 75 µm	28.8	26.39
Thru 45 µm	10.0	5.65
Differential Scanning Calorimetry		
onset Temperature °C	68.02 ± 1.03	62.80 ± 0.11
enthalpy (normalized, J/g)	0.86 ± 0.10	9.72 ± 0.31
peak temperature °C	74.75 ± 1.42	73.83 ± 0.61

[a] Results reported as average ± standard deviation unless otherwise indicated. Recorded from two sample reps for each lentil flour.
[b] Results reported from 1 sample

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Phase 2- Preliminary Testing and Ingredient Functionality Assessment

Bone-In Fried Chicken Thighs

Breading Composition

Table 2: Moisture and fat composition of raw breading mixtures

	Coating Type						
	Control	**T20**	**T30**	**T40**	**UT20**	**UT30**	**UT40**
Moisture (%)	10.99	10.39	10.05	9.26	10.90	10.77	10.81
Fat (%)	1.4	1.4	1.7	<0.5*	1.4	1.5	1.40

* <0.5% reported from the lab.

Moisture content of the raw breading mixes made with the treated lentil flour inclusions was reduced with increasing treated lentil flour inclusion. The trend is due to the low moisture content of the treated flour. The untreated lentil flour was more similar to the control moisture content suggesting the initial moisture level of the untreated lentil flour and base of the breading coating were similar. No clear trends in the changes to the fat content of the coating systems were observed. The fat content values reported for the 40% treated lentil flour inclusion samples were not aligned with the rest of the trials and differences in results may be due to day-to-day testing variance.

Table 3: Moisture and fat composition of cooked breading on chicken skin

	Coating Type						
	Control	**T20**	**T30**	**T40**	**UT20**	**UT30**	**UT40**
Moisture (%)	8.42	12.85	8.18	5.4	6.97	8.51	7.98
Fat (%)	52.40	54.35	49.5	53.25	56.45	54.65	54.95

No clear trends in changes to moisture content were observed in the final cooked chicken coating. This may be due to large variations in the sample composition. The inclusion of lentil flour generally increased the fat uptake in the cooked breaded chicken skins compared to the control (with the exception of the 30% treated lentil flour sample).

Breading Pickup

Table 4: Average breading pickup (% of total weight of raw breaded chicken thigh) of chicken coated with the control breading system, treated and untreated lentil flour

Sample	Breading Pick up (%)	SD
Control	2.9	± 0.42
T20	2.62	± 0.54
T30	2.55	± 0.38
T40	2.59	± 0.57
UT20	3.00	± 0.62
UT30	2.63	± 0.18
UT40	2.89	± 0.31

Generally, the inclusion of lentil flour decreased the breading pick up percent. Differences in breading pickup was observed between the treated and untreated lentil flours. In general, untreated lentil flour has higher pickup than the treated lentil flour. The only lentil sample with breading pickup greater than the control was the UT20 sample however this was not necessarily significantly different than the control

Final Frying Yield

Table 5: Cook yield (% of cooked breaded weight from raw breaded weight) of fried chicken thighs coated with a Newly Weds breading system, treated and untreated red lentil flour.

Sample	Cook Yield (%)	SD
Control	67.02	± 3.82
T20	66.55	± 3.94
T30	66.01	± 2.9
T40	65.88	± 3.04
UT20	64.37	± 3.45
UT30	68.19	± 2.28
UT40	66.11	± 3.65

Overall a slight reduction in the cook yield was observed with the inclusion of lentil flour in the breading system. Only the untreated 30% lentil flour inclusion had a higher cooked yield compared to the control No trends were observed for cook yield with respect to increased lentil flour inclusion levels.

Sensory Evaluation

Table 6: Sensory evaluation of fried chicken thighs coated with treated red lentil flour and the Newly Weds coating system.

Sensory Characteristic	Control	SD	T20	SD	T30	SD	T40	SD
Coating Coverage	8.75	± 0.50	8.3	± 1.0	8.8	± 0.5	9.0	± 0.0
Coating Firmness	4.75	± 1.50	6.50	± 1.00	5.75	±2.36	5.75	± 1.26
Overall Coating Color	7	± 1.29	8.0	± 1.5	6.0	± 1.3	7.0	± 1.5
Coating Crispiness	6.25	± 0.96	7.0	± 0.8	6.8	± 1.7	6.8	± 1.9
Coating Crunchiness	5.5	± 1.3	6.0	± 1.4	5.5	± 2.4	5.6	± 2.1
Off Flavor Intensity	2.8	± 2.2	3.0	± 2.5	3.3	± 2.6	2.8	± 1.7
Moistness	7.3	± 1.3	8.3	± 1.0	7.5	± 1.0	8.0	± 0.8
Greasiness	5.8	± 1.7	5.0	± 2.2	5.8	± 1.5	6.3	± 1.7
Overall Texture	7.0	± 1.7	8.0	± 1.0	7.0	± 1.3	7.0	± 1.3
Overall Quality	7.0	± 1.7	7.0	± 1.9	7.0	± 1.0	7.0	± 1.6

In general, 20% treated lentil flour inclusion showed an initial increase in many sensory quality characteristics. Further increasing the lentil inclusion levels beyond 20% did not necessarily show an increased improvement in the sensory characteristics as compared to the control samples. This characteristic was observed in the following sensory attributes

- Coating firmness
- Overall colour acceptability: Inclusions greater than 20% may result in excess colour development due to amino acid content (e.g. lysine) in the lentil flour.
- Coating crispiness
- Coating crunchiness
- Overall texture: Beyond 20% lentil flour inclusion the texture advantages may have decreased due to the presence of other texture quality issues (e.g. powdery mouth feel, reduced cohesion in the breading system due to reduction in gluten network)
- Greasiness

Moistness: an initial increase in the moistness perception of the 20% treated lentil flour inclusion was observed, increasing the lentil flour beyond 20% inclusion to 30% and 40% inclusion resulted in slightly reduced moistness perception but values were still higher than the control sample.

Coating coverage: At T20 lentil flour inclusion, an initial drop in coverage was noted however, as lentil content was further increased, an increase in coverage was observed. This could be due to lentil flour properties (stickiness and adhesion due to starch damage or starch gelatinization) improving the coating coverage in the samples.

Overall acceptability: Regardless of the inclusion of lentil flour all samples had the same overall acceptability. Texture difference did not correlate to differences between samples in their overall quality score.

Table 7: Sensory evaluation of fried chicken thighs coated with untreated red lentil flour and a Newly Weds coating system.

Sensory Characteristic	Control	SD	UT20	SD	UT30	SD	UT40	SD
Coating Coverage	8.50	± 1.00	8.75	± 0.50	9.00	± 0.00	9.00	± 0.00
Coating Firmness	7.00	± 1.41	6.25	± 1.50	6.50	± 2.52	6.75	± 0.96
Overall Coating Color	7.75	± 0.50	8.30	± 0.96	8.00	± 0.82	8.25	± 0.50
Coating Crispiness	8.25	± 0.50	6.75	± 1.26	8.25	± 0.50	6.00	± 0.82
Coating Crunchiness	7.25	± 0.96	5.50	± 2.08	6.50	± 1.73	5.50	± 1.00
Off Flavor Intensity	2.00	± 2.00	2.50	± 1.73	1.75	± 0.50	1.50	± 0.58
Moistness	8.00	± 1.41	8.25	± 0.96	7.50	± 1.29	8.00	± 1.41
Greasiness	5.75	± 2.22	5.25	± 2.63	5.25	± 2.06	5.50	± 2.65
Overall Texture	8.00	± 0.00	7.50	± 1.00	7.80	± 0.50	7.75	± 0.96
Overall Quality	8.00	± 0.00	7.80	± 0.50	7.30	± 0.96	8.00	± 1.15

Coating coverage: the inclusion of untreated lentil flour increased the coating coverage appearance of samples as compared to the control.

Coating firmness: A reduction in coating firmness was observed with the inclusion of untreated lentil flour in the breading system. Further increasing the lentil concentration in the breading system helped to improve firmness but all inclusion levels were lower than the control sample. Reduced firmness in lentil inclusion corelated to the reduced crispiness and crunchiness sensory attributes.

Overall coating colour: Coating colour acceptability was increased with lentil flour inclusion with the greatest increase compared to the control at 20% untreated lentil flour inclusion.

Coating crispiness: An initial reduction in coating crispiness was observed with a 20% inclusion of lentil flour, however at 30% untreated lentil flour inclusion, crispiness perception rebounded to match the control sample values however further inclusion to 30% reduced the crispiness values again.

Coating crunchiness: Untreated lentil flour inclusion reduced the crunchiness of samples. This may be due to the lack of gluten network formed from the dilution of the wheat ingredients in the system as well as the lack of gelatinized starches (present in the treated samples) to form a more cohesive network to create texture.

Off flavour intensity: A low intensity of off flavours was detected in samples. A slight increase in intensity was observed at 20% untreated lentil flour inclusion. The high heat, low moisture process conditions were likely able to drive off off-flavours that are typically associated with lentil flours.

Greasiness: Lentil flour inclusion reduced the perceived greasiness of the samples. All lentil flour inclusions were considered less greasy than the control.

Overall texture: The inclusion of lentil flour generally slightly reduced the overall texture acceptability of samples compared to the control. However, the variability in responses was high.

Overall quality: Control and untreated lentil flour inclusions resulted in similar overall quality acceptability scores.

Instrumental Colour

Table 8: Instrumental Colour of fried chicken thighs coated with a control Newly Weds breading system, treated and untreated lentil flour.

	L*	a*	b*	Delta E
Control	55.0	9.1	30.5	
T20	54.4	10.2	31.4	1.6
T30	53.2	13.4	31.7	4.8
T40	54.1	12.0	32.9	3.9
UT20	51.0	13.7	28.7	6.3
UT30	48.2	12.3	26.0	8.7
UT40	49.7	14.0	27.7	7.7

Figure 1: Control Newly Wed Breaded Thigh

Figure 2: 20% untreated lentil flour breaded thigh

Figure 3: 30% untreated lentil flour breaded thigh

Figure 4: 40% untreated lentil flour bread thigh

Figure 5: 20% treated lentil flour breaded thigh

Figure 6: 30% treated lentil flour breaded thigh

Figure 7: 40% treated lentil flour breaded thigh

Colour perception differences of the treated red lentil flours compared to the control was less than the untreated red lentil flour compared to the control. Increased lentil inclusion level results in increased colour changes especially with respect to lightness (L*) and redness (positive a*) values. At 40% inclusion, the colour intensity plateaus, and perceptible differences indicated by ΔE decreases. This may be a result of the lightness-darkness (L* value) overpowering the other hue values.

Instrumental Texture Analysis

Table 9: Change in texture (puncture force, g) of fried chicken thighs coated with a control Newly Weds breading system, treated and untreated lentil flour held under a heat lamp at 50°C.

	Puncture Force (g)						
Time	**Control**	**T20**	**T30**	**T40**	**UT20**	**UT30**	**UT40**
0	103	61	16	51.5	27.8	76	172.8
15	46	138.3	9.3	29.5	12.8	27.5	14.8
30	41.8	25	14	37.3	17.3	12.3	15.5
45	17	27.3	122	NP	46	45.5	27
60	10	67.3	70.3	10.5	12.3	10.5	25.3

In the heat lamp trials, lentil flour inclusion generally resulted in reduced puncture force compared to the control samples. However, puncture force of samples varied greatly (results not presented here). Data collected from the clam shell holding test indicated that lentil flour generally increased the initial puncture force of the chicken coatings. In both trials, no clear trends were observed on effects of lentil flour inclusion level or effect of treated vs untreated lentil flour on puncture force of coatings at time = 0.

Heat lamp holding at 50°C resulted in a clear drop in puncture force for the control samples throughout the holding period. Both treated and untreated red lentil samples at the three inclusion levels did not demonstrate this clear trend with some samples regaining puncture force over the holding period. This could potentially be due to the moisture migration characteristics between the lentil flours compared to the wheat-based control flours.

Table 10: Change in texture (puncture force, g) of fried chicken thighs coated with a control Newly Weds breading system, treated and untreated lentil flour held in a clam shell take out container.

	Puncture Force (g)						
Time	**Control**	**T20**	**T30**	**T40**	**UT20**	**UT30**	**UT40**
0	68	83.3	9.5	85.3	NP	86.8	141
15	43.8	40.5	37.3	49	NP	44	7
30	NP	83.3	15	NP	42	10.5	135.5
45	NP	NP	NP	NP	9.8	34.8	8.5
60	NP	NP	7.5	NP	6.5	14.5	5.5

NP – notes a measurement where no distinct peak hardness was measure indicated on the graph produced by the CT3 texture analyzer

In the clam shell hold stability trials, the control samples demonstrated puncture force degradation at 30 min of holding time. Lentil flour inclusions were more capable of retaining their texture throughout the clam shell holding period however no clear trends on the effect of the treated vs untreated lentil flours or the effect of the lentil flour inclusion level. Treated lentil flour at 20% inclusion rates seemed to fare better in the clam shell test than the untreated samples but wide variability was observed in the texture analysis data. Completing a more thorough investigation of the effects of holding time on texture quality for select formulations is recommended to define these trends more clearly.

Boneless Chicken Tenders

Breading Composition

Table 11: Moisture and Fat composition of par fried whole fried chicken tenders coated with a control Newly Wed breading system, treated and untreated red lentil flour.

	Coating Type						
	Control	**T20**	**T30**	**T40**	**UT20**	**UT30**	**UT40**
Moisture (%)	52.69	61.04	60.87	61.22	61.63	59.39	61.70
Fat (%)	9.25	6.10	5.05	4.60	6.20	6.55	6.25

Table 12: Moisture and Fat composition of fully cooked whole fried chicken tenders coated with a control Newly Wed breading system, treated and untreated red lentil flour.

	Coating Type						
	Control	**T20**	**T30**	**T40**	**UT20**	**UT30**	**UT40**
Moisture (%)	49.53	46.08	48.98	53.07	54.71	56.44	54.42
Fat (%)	5.00	11.85	10.10	9.35	6.95	6.10	6.95

In general, the fat content of the chicken tenders containing lentil ingredients was greater than the control sample. Treated lentil flour coating systems contained more fat following frying than the untreated lentil flours.

Breading Pickup

Table 12: Average breading pickup of chicken coated with a control Newly Wed breading system, treated and untreated red lentil flour

Sample	Pre-Dust Pick up (%)	SD	Breading Pickup (%)	SD
Control	3.87	± 0.46	11.22	± 0.06
T20	3.75	± 0.58	14.09	± 2.07
T30	3.81	± 0.77	12.91	± 1.17
T40	2.99	± 1.81	13.32	± 1.82
UT20	4.12	± 0.49	12.94	± 0.51
UT30	4.05	± 0.22	12.52	± 0.75
UT40	4.19	± 0.38	13.62	± 1.61

Untreated red lentil flours demonstrated greater pre-dust pick up than the control and treated red lentil flours. All red lentil flours (treated and untreated) had greater breading pickup as compared to the control.

Par-fry Yield

Table 13: Par fry cook yield of fried chicken tenders coated with a Newly Weds breading system, treated and untreated red lentil flour.

Sample	Cooking Yield (%)	SD
Control	86.03	± 1.4
T20	86.25	± 3.00
T30	83.66	± 2.71
T40	85.41	± 1.58
UT20	88.67	± 0.51
UT30	85.67	± 1.39
UT40	85.41	± 1.58

Par-fry cooking yield of red lentil systems was similar to the control samples. At 20% lentil flour inclusion cooking yield was similar or greater than the control sample (treated and untreated respectively). These results indicate that as lentil flour inclusion levels increase, cooking yield is somewhat reduced.

Final Frying Yield

Table 14: Cook yield of fried chicken tenders coated with a Newly Weds breading system, treated and untreated red lentil flour.

Sample	Cooked Yield (%)	SD
Control	69.18	± 2.4
T20	68.03	± 3.09
T30	68.44	± 2.07
T40	73.82	± 2.25
UT20	77.63	± 1.14
UT30	79.04	± 0.9
UT40	76.59	± 1.49

Final frying yield of untreated lentil flours was typically greater than treated lentil flours and control sample. Maximum final frying yield was demonstrated by the untreated red lentil flour at 30% inclusion of the chicken tender breading coating.

Sensory Evaluation

Table 15: Sensory evaluation of fried chicken tenders coated with untreated red lentil flour and a Newly Weds coating system.

Sensory Characteristic	Control	SD	UT20	SD	UT30	SD	UT40	SD
Coating Coverage	8.3	± 1.1	8.7	± 0.5	8.7	± 0.5	8.8	± 0.4
Coating Firmness	6.2	± 2.2	6.3	± 1.6	6.8	± 1.3	6.5	± 1.4
Overall Coating Color	4.5	± 1.5	6.2	± 1.3	6.5	± 1.0	6.5	± 1.0
Coating Crispiness	4.0	± 1.6	4.5	± 1.6	5.0	± 1.7	4.0	± 1.8
Coating Crunchiness	4.2	± 2.0	5.2	± 0.8	4.5	± 1.6	3.7	± 1.8
Off Flavor Intensity	2.3	± 1.9	2.5	± 2.0	2.0	± 1.5	2.2	± 1.9
Moistness	5.0	± 2.4	5.2	± 1.5	4.5	± 1.2	4.3	± 2.1
Greasiness	4.3	± 1.8	3.2	± 1.2	3.7	± 1.5	3.2	± 1.2
Overall Texture	5.3	± 1.2	5.5	± 1.4	5.5	± 1.0	5.3	± 0.8
Overall Quality	5.7	± 1.6	5.7	± 1.5	5.7	± 1.0	6.0	± 1.3

Coating coverage: slight increase in coating coverage with lentil flour inclusion, no effect of lentil flour inclusion level on coverage.

Coating firmness: slight increase in coating firmness with lentil flour inclusion, very similar to control

Overall coating colour: lentil flour inclusion greatly increases the overall colour acceptability of chicken tenders compared to the control. Marginal colour acceptability from 20% inclusion to 30% inclusion.

Coating crispiness: Initial increase in coating crispiness of 20% inclusion vs control and further increase at 30% inclusion.

Coating crunchiness: increase in coating crunchiness at 20% lentil flour inclusion as compared to the control, further increase in lentil flour inclusion rates reduces crunchiness level.

Off-flavour intensity: like control, no lentil related off-flavours were noted

Moistness: initial increase in moistness with 20% inclusion of lentil flour (like control). Further increase in lentil flour inclusion level further reduced moistness values.

Greasiness: Decrease in greasiness level of samples with lentil flour inclusion. No clear reduction in greasiness with increased inclusion level of lentil ingredients.

Overall texture: slightly improved (vs control) with lentil flour inclusion.

Overall quality: slight increase in overall quality of tenders at 40% untreated lentil flour inclusion but all samples were similar in overall quality acceptability to the control.

Table 16: Sensory evaluation of fried chicken tenders coated with treated red lentil flour and a Newly Weds coating system.

Sensory Characteristic	Control	SD	T20	SD	T30	SD	T40	SD
Coating Coverage	8.7	± 0.8	8.3	± 1.6	8.3	± 0.8	8.3	± 1.0
Coating Firmness	6.0	± 1.5	7.5	± 0.8	6.8	± 1.5	7.2	± 1.2
Overall Coating Color	3.8	± 0.4	6.8	± 1.6	7.0	± 0.9	7.2	± 0.8
Coating Crispiness	3.5	± 0.8	7.2	± 0.4	6.2	± 0.8	6.0	± 0.6
Coating Crunchiness	3.3	± 1.0	6.7	± 0.8	5.7	± 1.0	5.8	± 1.6
Off Flavor Intensity	1.5	± 0.8	2.0	± 1.1	2.0	± 1.3	1.8	± 0.8
Moistness	4.7	± 1.6	5.3	± 1.9	4.3	± 1.0	4.7	± 1.0
Greasiness	4.0	± 1.4	3.7	± 1.4	3.8	± 1.5	4.7	± 1.6
Overall Texture	5.2	± 1.0	6.8	± 1.0	6.3	± 0.5	7.2	± 0.4
Overall Quality	6.0	± 0.6	7.0	± 0.9	6.5	± 0.5	7.5	± 0.6

Coating coverage: some reduction in coverage with lentil flour inclusion but still similar to control

Coating firmness: initial increase in coating firmness with 20% lentil inclusion and then some firmness loss with increasing lentil flour inclusion rates. All lentil inclusion rates higher firmness than control.

Overall coating colour: increase in overall colour acceptability with each increasing lentil flour inclusion level.

Coating crispiness: significant increase in coating crispiness with lentil flour inclusion compared to control. As lentil flour inclusion rate increases, some slight drop in crispiness scores (but all lentil inclusion rates are greater than the control)

Coating crunchiness: significant increase in coating crunchiness with lentil flour inclusion compared to control. As lentil flour inclusion rate increases, some slight drop in crunchiness scores (but all lentil inclusion rates are greater than the control)

Off-flavour intensity: some slight increase in off flavour detected with lentil flour inclusion. Intensity of off-flavour did not increase with increase lentil content

Moistness: some slight initial increase in moistness at 20% inclusion rate. Moistness scores decrease at 30% and 40% inclusion compared to 20% inclusion.

Greasiness: initial reduction in greasiness score of 20% and 30% lentil flour inclusion levels. At 40% inclusion, greasiness score was greater than the control score

Overall texture: increases with lentil flour inclusion with the greatest overall texture score at 40% lentil flour inclusion rate

Overall quality: lentil flour inclusion increased overall quality score of chicken tenders with the greatest acceptability at 40% lentil flour inclusion.

Instrumental Colour

Table 17: Instrumental colour of fried chicken tender coated with a control Newly Weds breading system, treated and untreated lentil flour.

Sample	L*	a*	b*	Delta E
Control	58.4	15.2	30.4	
T20	54.3	19.3	36.8	8.7
T30	59.4	18.4	36.1	6.7
T40	57.5	19.6	36.5	7.6
UT20	63.9	15.8	34.6	7.1
UT30	62.5	18.0	36.0	7.6
UT40	64.2	17.4	35.6	8.2

Colour of lentil flour inclusions in chicken tenders was generally characterized as more red (a*) and more yellow (b*) as compared to the control sample. The L* value (lightness or darkness) was related to the type of lentil flour included in the formulation; the untreated samples yielded a brighter product. Overall, the changes in the colour perception (delta E value) of the lentil flour chicken tenders as compared to the control were at a similar level of differences (between <2 – 10, perceptible differences at a glance).

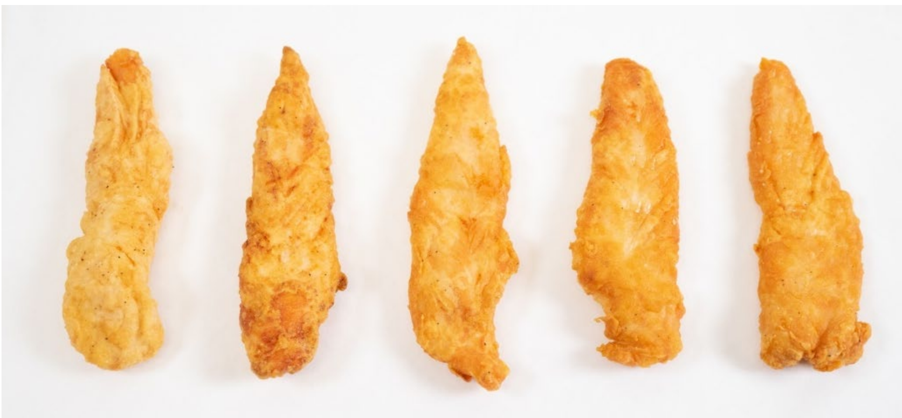

Figure 8: Control and Treated Red Lentil Flour Coated Chicken Tenders. L-R Newly Wed Control (water dip), Newly Wed Control (Milk Dip), 20% Treated Lentil Flour, 30% Treated Lentil Flour, 40% Treated Lentil Flour.

Interestingly, the colour development of lentil flour inclusions in breading coating systems was similar to the level of colour development achieved in the control sample when a dairy ingredient in included in the product formulation as seen in Figure 8. This may lead to the opportunity to replace dairy based ingredients in these systems with an inclusion of lentil flour leading to dairy free or potentially allergen free versions of these products. This colour matching was more pronounced in the use of treated lentil flour as compared to untreated lentil flour (Figure 9) which did not achieve a similar level of colour development in the chicken tender until a min 40% inclusion of untreated lentil flour in the coating system.

Figure 9: Control and untreated red lentil flour coated chicken tenders. L-R Newly Wed Control (water dip), Newly Wed control (Milk Dip), 20% untreated lentil flour, 30% untreated lentil flour, 40% untreated lentil flour.

Instrumental Texture Analysis

Table 18: Texture (puncture force, g) of fully cooked chicken tenders coated with a control Newly Weds breading system, treated and untreated lentil flour held under a heat lamp at 50°C.

	Peak Force (g)						
Time	**Control**	**T20**	**T30**	**T40**	**UT20**	**UT30**	**UT40**
0	1403.3	2463.8	1677.5	1766.5	1748.5	1813.8	1838.3
15	1409.3	3072.3	3511	3099.5	1354	2286.5	2633.3
30	1555.8	3534	2610.5	1734.3	1656.8	2721	1945
45	2102	3292.5	2303	1982.8	2061.8	2647.5	2263.3
60	1563.5	2787	3169.3	2527	2152.5	3238.5	3243.5

The initial puncture force of the chicken tenders formulated with lentil flour ingredients was higher than the initial puncture force of the control chicken tenders. The chicken tenders formulated with the treated lentil flours had a high initial jump at the 20% inclusion level which diminished with increasing treated lentil flour inclusion. Untreated lentil flour texture was relatively steady with increasing inclusion levels. Throughout the heat lamp hold time, the control chicken tender generally retained its texture. The chicken tenders formulated with lentil flours demonstrated an increase in puncture force over the holding period. This increase in texture may be due to the starch retrogradation properties of lentil flours creating a higher degree of crystallinity in the coating system causing the development of a harder crust of the coating.

Table 19: Change in texture (puncture force, g) of fully cooked fried chicken tenders coated with a control Newly Weds breading system, treated and untreated lentil flour held in a clam shell take out container.

			Peak Force (g)				
Time	**Control**	**T20**	**T30**	**T40**	**UT20**	**UT30**	**UT40**
0	2368	2086.5	1845.8	2582.3	1987.5	1482.5	1917.3
15	2321.8	2310	2224.5	2679.8	2153	1826.8	1898.5
30	1218.5	3386.5	2722	2652	2409	2250.5	2451.5
45	1989.3	3567	2242	3530.3	2463.8	2951.0	2735.5
60	3143	3326.8	3824.5	3177	2644	2593.3	2193.3

When the chicken tenders are held within a clam shell style take out container, the texture of the control sample has an initial firm, strong network and has a higher initial puncture force than most of the tender coatings formulated with lentil flour. Within the holding period, the control chicken tenders demonstrated a loss of texture at approximately 30 min of holding, as the sample further cooled, the puncture force increased. The lentil flour coating systems did not demonstrate this dip in texture suggesting that the lentil flour inclusion helped to retain texture at the mid-point of the holding time.

Phase 3 – Formulation Optimization and Quality Assessments

Based on the results from phase 2, treated lentil flours were selected for optimization in fried coating and batter applications. Sensory and instrumental results indicate that treated lentil flour improves desired texture characteristics of coated fried products including coating firmness, crunchiness, and crispiness. Treated lentil flours also rapidly produce a desirable even golden brown coating on fried products.

Bone-in Fried Chicken Thighs

Bone-in fried chicken thighs were optimized to maximize the amount of lentil flour in the breading system while maintaining the desirable fried coating qualities identified in Phase 2 of the project. Bone in chicken thighs were prepared using a coating of 60g of the 30% treated lentil flour coating system and 10 g of water. The addition of water to the coating system simulated commercial breading conditions in which a single batch of breading is used to coat multiple batches of chicken resulting in the addition of moisture from the chicken to the coating mixture.

The addition of moisture to the breading process assists in developing the desired flaky texture in the final cooked product to resemble the commercial products. The 30% treated lentil flour coating system was selected as the product displayed an even golden-brown colour and firm crunchy texture without developing a bitter scorched taste in the coating which was present at higher lentil flour inclusions.

Breading Pick up

Table 20: Average breading pickup (% of total weight of raw breaded chicken thigh) of chicken thighs coated with 60g of coating system and 10 g of water.

Optimized Product	Predust Pickup (%)	SD	Breaded Pick up (%)	SD
Optimized Control Thigh	2.22	±0.83	12.26	±0.93
Optimized T30 Thigh	2.05	±0.16	11.95	±1.08

Cook Yield

Table 21: Average cook yield (% of total weight of raw breaded chicken thigh) of chicken thighs coated with 60g of coating system and 10 g of water.

Optimized Product	Cook Yield %	SD
Optimized Control Thigh	78.76	±1.47
Optimized T30 Thigh	76.73	±1.23

Instrumental Colour

Table 22: Instrumental colour of commercial fried chicken thighs and fried chicken thighs coated with 60g of coating system and 10 g of water.

	L*	a*	b*
KFC	46.47	18.67	30.73
Popeyes	47.70	18.85	31.30
Optimized Control	49.75	15.85	30.4
Optimized T30	45.3	18.8	31.8

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Sensory commentary "Chef perspective"

The two fried chicken commercial controls selected in this study included Kentucky Fried Chicken (KFC) Original Recipe chicken and Popeyes mild signature chicken. Both controls displayed unique fried chicken characteristics. The KFC fried chicken displayed a soft dark coating with crunchy edges and displayed distinct flecks of seasoning. The Popeyes fried chicken displayed a firm crunchy coating over the entire piece of chicken with an even golden brown colour and distinct flakes of breading.

The T30 breading was selected as it produced fried chicken with an even golden brown coating and reduced undesirable brown flavors. By adding moisture to the breading system both the control and the lentil coatings developed the flaky characteristics of the Popeyes thigh. While the texture of the fried chicken produced using the control coating displayed a soft coating with crunchy edges similar to the KFC thigh. The T30 thigh produced an evenly golden brown coating with a firmness similar to the Popeye's fried chicken product. The addition of the treated lentil flour resulted in rapid colour development of product which reduced the cooking time from 12 minutes to 9 minutes while still achieving an internal cook temperature of 90°C.

Both the optimized control and T30 products were held for thirty minutes at 50°C under a heat lamp. After thirty minutes of holding the T30 product displayed a firm crunchy coating with good adhesion to the piece of chicken while the coating of the control product displayed noticeable softness and separation from the piece of chicken. These results indicate that inclusions of lentil flour in fried chicken coating systems form firm coatings that may have the potential to improve the quality of products held under heat lamps for short periods of time during periods of food service.

Photos

Figure 10: Kentucky Fried Chicken

Figure 11: Popeyes mild signature thigh

Original Recipe Thigh


Figure 12: 30% Treated Red Lentil Flour Thigh


Figure 13: Newly Wed Breading System

Boneless Chicken Tenders

Fried boneless chicken tenders were optimized to maximize the amount of lentil flour in the coating system while still maintaining desirable qualities of the fried chicken tenders as identified in Phase 2 of this project. Chicken tenders were produced using a three part coating system consisting of a 100% treated lentil flour pre-dust, water dip, and a final breading consisting of 30g of 40% treated lentil flour breading and 10g of water. Similar to the optimized bone-in fried chicken the addition of water to the coating system simulated commercial preparations in which one batch of coating is used to bread multiple batches of chicken. The additional moisture in the system helps to develop the flaky appearance of the fried coating resulting in a crunchy texture.

Boneless chicken tenders were produced with a cook time of 3 minutes which allowed for a higher inclusion of treated lentil flour, 40%, compared to the bone-in chicken thighs. The shorter cook time reduces the potential of developing scorched or over cooked off flavor in the coating while the rapid colour development produces a product with an even golden brown colour.

Breading Pick up

Table 23: Average breading pickup (% of total weight of raw breaded chicken tenders) of chicken tenders coated with 30g of 40% treated lentil flour coating system and 10 g of water.

Optimized Product	Pre dust Pick up (%)	SD	Breaded Pick up (%)	SD
Control Tender	2.95	0.17	23.79	0.86
T40 Tender	2.94	0.58	24.46	0.7

Cook Yield

Table 24: Average cook yield (% of total weight of raw breaded chicken tenders) of chicken tenders coated with 30g of 40% treated lentil flour coating system and 10 g of water.

Optimized Product	Cook Yield (%)	SD
Control Tender	79.04	4.9
T40 Tender	76.35	1.39

Instrumental Colour

Table 25: Instrumental colour of commercial fried chicken tenders and fried chicken tenders coated with 30g of 40% treated lentil flour coating system and 10 g of water.

	L*	a*	b*
KFC	41.9	14.1	25.7
Popeyes	52.1	19.3	37.0
Optimized Control	56.5	15.9	31.6
Optimized T30	48.1	22.3	35.7

Sensory commentary "Chef perspective"

Both the optimized control and T40 lentil coating systems produced flaky coatings similar to the commercial KFC and Popeyes products. Overall the optimized products were not directly comparable to the commercial products as both the KFC and Popeyes products displayed characteristics unique to the individual brands such as seasoning and the size of the chicken tenders.

The chicken tenders coated with a 40% treated lentil flour coating did display qualities that may be desirable for commercial applications such as a firm crunchy coating and rapid colour development in par frying or fast frying applications.

Based on the sensory results from phase 2 of the project, the addition of treated lentil flours significantly increased the positive attributes associated with breaded and fried products including firmness and crunchiness of the fried coatings compared to the control coating system. Based on the optimized bone in chicken thigh trials the increased coating firmness could result in improved holding times under heat lamp conditions.

Based on the colour results in Table 25 and Figures 16 and 17, the 40% treated lentil flour inclusion resulted in an even golden brown colour on the final product compared to the control as both products were cooked for 3 minutes at 350°F. This rapid colour development could be beneficial in food service applications that require lean proteins such as fish, boneless chicken or shrimp to be breaded and fried to a golden brown colour while minimizing moisture loss in the product. Similarly, treated lentil flour inclusions could improve colour development in commercial food processing applications that require a product to be par fried then reheated by the consumers at which point additional colour development may be difficult to achieve.

As shown in figure 8, treated lentil flour inclusions have the ability to rapidly develop even golden brown colours in fried products without the use of allergen ingredients such as milk or eggs. In addition to the positive effects of treated lentil flours on the overall quality of fried products, the replacement of allergen ingredients with treated lentil flour could produce a cleaner product ingredient list.

Photos

Figure 14: KFC Original Recipe Tender

Figure 15: Popeyes Original Recipe Tender

Figure 16: 40% Treated Lentil Flour Tender

Figure 17: Newly Wed System Tender

Fish

Preliminary trials of battered fried fish were performed to identify the maximum inclusion of treated lentil flour in these applications based on the characteristics of treated lentil flour inclusions in fried chicken applications.

Frozen haddock fillets were coated with a control batter system consisting of a wheat flour predust and control coating batter as well as a treated lentil flour coating system consisting a treated lentil flour predust and lentil flour batters consisting of 40%, 50% and 60% treated lentil flours.

Due to the short cooking time of these applications and high moisture content of batters and the reduced potential for the development of scorched off flavors, treated lentil flour inclusion levels of 40%, 50% and 60% were assessed. These initial trials determined that 40% is the maximum inclusion of treated lentil flour in batters as higher inclusions result in undesirable over browning of the product resulting in negative flavour attributes.

Instrumental Colour

Table 26: Instrumental colour of battered fried haddock fillets coated with 40% treated lentil flour coating system (50g T40, 0.8 g of baking soda and 125g of sparkling water).

Optimized Product	L*	a*	b*
T40 Battered Haddock	36.15	14.55	23.80
Control Battered Haddock	42.11	18.41	29.75

Sensory commentary "Chef perspective"

As seen in Figure 18 and 19. fried battered haddock coated with a 40% treated lentil flour system displayed improved coating colour development compared to the control without the use of egg or milk in the coating. The treated lentil flour batter produced an attractive crisp shattering coating that did not become soft when held under a heat lamp for thirty minutes. Despite the attractive texture of the coating, the reduced wheat content of the batter resulted in a porous coating structure allowed oil to permeate the coating during the cooking process resulting in an oily final product.

Further development of treated lentil flours in batter coating systems will require the assessment additional functional ingredients to improve the structure of the coating to prevent oil from permeating the product during the cooking process..

Photos

Figure 18: 40% Treated Lentil Flour Battered Haddock

Figure 19: Newly Wed Control Battered Haddock

Fried Potatoes – Fries

Preliminary trials of coated fry products were performed to identify the maximum inclusion of treated lentil flour in these applications based on the characteristics of treated lentil flour inclusions in fried chicken applications.

Russet potatoes were cut using a fry punch, steamed, cooled, frozen, individual samples were coated with a control batter system or a treated lentil flour coating system consisting of 40%, 50% and 60% treated lentil flours.

These initial trials determined that 40% is the maximum inclusion of treated lentil flour in the coatings as higher inclusions result in undesirable over browning of the product and a thick coating on the fries.

Instrumental Colour

Table 27: Instrumental colour of commercial coated fries and fries coated with 40% treated lentil flour coating system (30g T40 and 70g water).

Optimized Product	L*	a*	b*
T40 Coated Fries	51.6	13.3	29.8
McCain Super Fries	49.3	9.85	23.65

Sensory commentary "Chef perspective"

Fries produced with a 40% treated lentil flour coating displayed an even golden brown colour, crisp texture, and a visible coating on the product.

Overall, the 40% treated lentil flour coating produced an acceptable product. However, depending on the quality specifications of the manufacturer treated lentil flours may not be acceptable for all products based on desired color and texture. As seen in figure 20 and 21 McCain Super fries do not display a visible coating and are lighter in color compared to the treated lentil flour coated product.

Photos

Figure 20: 40% Treated Lentil Flour Coated Fries

Figure 21: McCain Super Fries

Conclusions & Recommendations

Conclusion

Breading systems containing treated lentil flours displayed desirable changes to the colour and texture of coated fried bone in thighs and boneless chicken tenders compared to the Newly Wed control breading system. Inclusions of treated lentil flours at 20%, 30%, and 40% produced an even golden brown colour and improved coating firmness resulting in a desirable crispy and crunchy texture. A 20% treated lentil flour inclusion produced significant texture differences from the control breading system with minimal changes at higher inclusion levels. A 40% treated lentil flour inclusion produced the most intense golden brown colour without any significant undesirable effects on the flavor of the product.

The use of untreated lentil flours at 20%, 30%, and 40% inclusion levels resulted in slight increases in the browning of the product compared to the control coating systems without significant improvements to the firmness, crispiness or crunchiness of the coating systems.

Inclusions of 40% treated lentil flour in batters produced crisp battered products with an even golden brown color. However further development is required to improve the structure of the coating to reduce oil absorption and meet specific quality characteristics of manufacturers

Recommendations

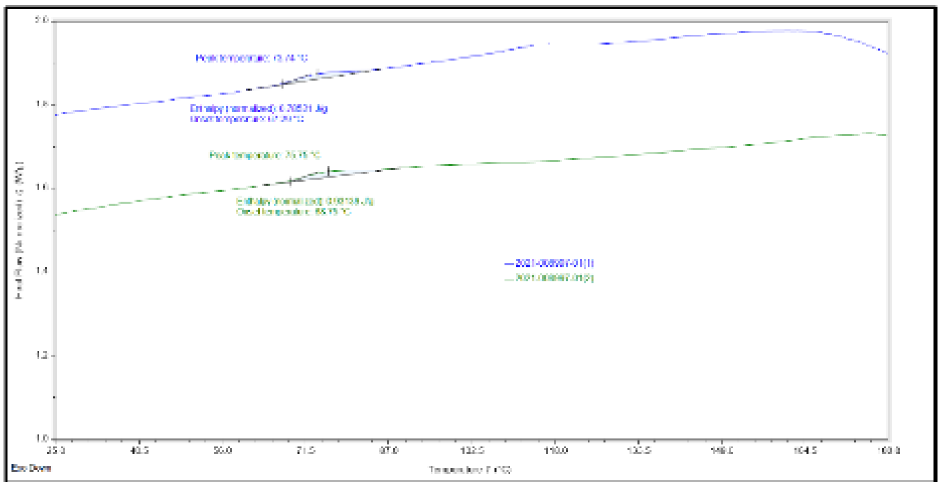
Treated lentil flours display positive effects on the colour and texture of coated fried products when included at rates of 20-40% of the wheat ingredient in a commercial breading application.

The positive attributes of treated lentil flour in coated fried applications presents the following opportunities in commercial applications:

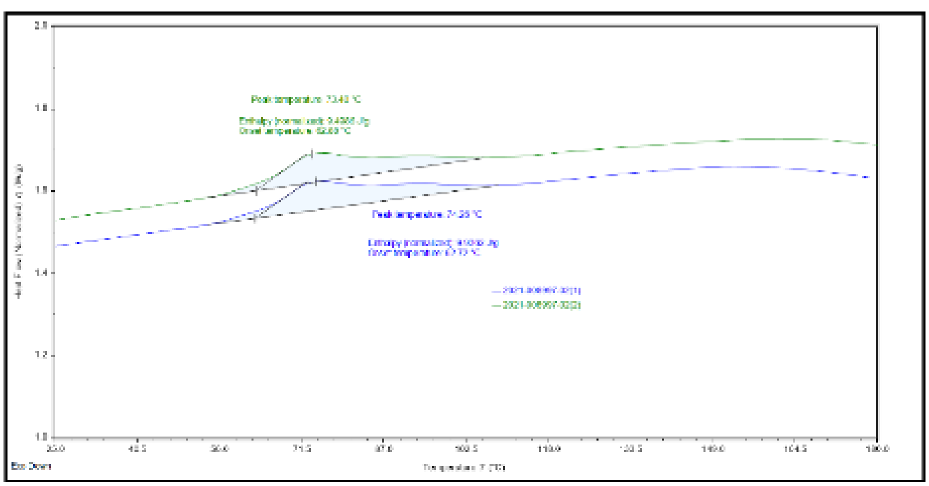
- Potential to replace allergen ingredients used to develop color in products such as milk and egg in coating systems.
- Rapid color development could result in reduced cook times when final product color is a quality target. Rapid color development could improve the cooked quality of fried products that are sensitive to moisture loss during cooking.
- Potential to improve the holding quality of fried products held under heat lamps by creating and maintaining a firm coating that adheres to the product.

Appendices

Appendix A: Differential Scanning Calorimetry Results



Differential Scanning Calorimetry results of treated red lentil flour



Differential Scanning Calorimetry results of untreated red lentil flour