

# Effect of pre-cooked yellow pea flour incorporation on wheat tortilla quality parameters

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## RESEARCH ARTICLE

### Abstract

Tortillas are a rapidly growing sector of the food market. With a trend in more health conscious consumers, pulse flours have the potential to increase tortilla markets by enhancing the nutritional value of tortillas. In this study, tortillas were made by substituting wheat flour with pre-cooked pea flour at a rate of 75.66, 83.83, and 92.00 g in 200 g batches (flour basis). For each pea flour addition level, water and addition of vital wheat gluten was optimised based on tortilla diameter and opacity. For all pea flour substitution rates, tortillas of comparable quality to a wheat control were made. Shelf-stability of optimal formulations for each pea flour substitution rate were studied over a 20 day period. It was found that all treatments and controls had similar decreasing trends in rollability scores over the storage time. Conversely, tortilla toughness values increased over time, where wheat had overall greater values throughout storage and a more rapid initial increase in toughness values. Tortilla extensibility for the pea flour treatments increased for the first 6 days of storage and decreased for the remainder. Wheat tortilla extensibility decreased throughout storage. Addition of pea flour to tortilla formulations can be accomplished without sacrificing quality and storage stability.

**Keywords:** tortilla fortification, pea flour, pulse flour, tortilla quality, shelf life

### 1. Introduction

It is estimated that bakery products in the United States accounted for a ~\$ 153 billion overall economic impact in 2016 (Anonymous, 2017). While this industry is currently seeing positive revenues, it is also undergoing major changes. In recent times, there has been a shift away from yeast leavened breads due to rising consumption of ethnic products. Here, tortillas are the fastest growing wheat product in terms of annual sales with an estimated \$ 13.8 billion in sales in 2015 (Kabbani, 2016). Along with these trends, there is push for food items that are perceived as healthy alternatives (Silow *et al.*, 2016). With shifts away from yeast leavened bread to non-traditional wheat products and foods marketed as healthy, sensory quality and product stability have become major issues that need to be addressed to further develop new markets.

To accommodate consumer demands of healthy foods, incorporation of pulse flours into baked goods has shown promise (Asif *et al.*, 2013). Pulses are a good source of dietary fibre, and contain approximately twice the protein of cereal grains. Pulse grains contain both soluble and insoluble fibre which have known benefits to cardiovascular and bowel health. Consumption of soluble fibre is correlated to lowering low density lipoprotein levels (Duane, 1997). Furthermore, the high fibre content of pulses, coupled with the high amylose content of pulse starch result in the slow glycaemic response of pulse foods (Araya *et al.*, 2002; Hardacre *et al.*, 2006). The proteins of pulses are rich in lysine and are generally more bioavailable compared to their cereal counterparts (Batistuti *et al.*, 1991). When eaten in conjunction with cereals, the proteins of both are considered complimentary, providing a good source of essential amino acids.

While pulse foods provide many nutritional benefits, there are also many hurdles to overcome when considering their incorporation into food products. Pulse products have strong off flavours described as bitter and beany with a tendency for astringency (Gupta, 1987; Hsu *et al.*, 1980; Zhao *et al.*, 2005). Anti-nutritional factors associated with pulse grains must also be addressed when formulating products (Akinyele *et al.*, 1988; Alain *et al.*, 2007; Horax *et al.*, 2004; Sammour, 2007). For example, pulse flours contain trypsin inhibitors. Trypsin inhibitors are protease inhibitors that prevent the digestion and subsequent absorption of proteins. To remove these anti-nutritional and sensory issues in pulse flours, pre-cooking is one viable option. When this is done, starch is gelatinised and proteins are denatured. This will result in increased water hydration properties, swelling, and denatured proteins may lose some functionality (Akinyele *et al.*, 1988; Alain *et al.*, 2007; Horax *et al.*, 2004; Sammour, 2007).

The incorporation of pulse flours into tortillas can provide many benefits and challenges. In a study by (Holt *et al.*, 1992), cowpea flour and peanut flour were successfully added into tortilla formulations at a rate of 24 and 46%, respectively, without sacrificing tortilla quality. However, anti-nutritional factors and strong off flavours can be associated with addition of pulse flours into foods (Gupta, 1987; Hsu *et al.*, 1980; Zhao *et al.*, 2005). In 'fact sheets' published by the USA Dry Pea and Lentil Council, flatbreads and tortillas containing 20% pre-cooked pulse flours with similar quality attributes to tortillas containing only wheat were made (Roberts, 2006a,b; Roberts and Cabella, 2006). In this work, the pre-cooked pulse flour was used because anti-nutritional factors and off flavours were removed during the cooking process. Consumer sensory panels with participants of 9-14 years of age demonstrated an overall aesthetic and taste appeal of 65 and 75% respectively for tortillas containing pre-cooked yellow pea flour (Roberts and Cabella, 2006). In this study, mission style control tortillas had an overall aesthetic and taste appeal of 75 and 100%, respectively.

There are limited studies on the functional properties of pulse flours when compared to cereal grains. From the few studies that have been completed, the solubility of flour components, hydration, moisture retention, and gelling properties of pulse flours would indicate the potential to alleviate sensory and product stability issues in developing healthier tortillas. For this reason, the objective of this research was to optimise and maximise the incorporation of a pre-cooked pea flour into wheat tortillas.

## 2. Materials and methods

### Materials

Grand Joaquin tortilla flour (11.4% protein, 2.7% fibre, and 1.2% lipid) was donated by Miller Milling Company (Minneapolis, MN, USA). Pre-cooked yellow pea flour (26% protein, 17% fibre, and 2.1% lipid) was kindly donated by (Inland Empire, Riverside, CA, USA). Vital wheat gluten was purchased from Bob's Red Mill (Milwaukie, OR, USA). NaCl was a white non-iodized table salt (Morton International, Inc. Chicago, IL, USA). Sodium stearoyl lactylate SSL 90 was kindly donated by Rita Corp. (Crystal Lake, IL, USA). Sodium propionate was purchased from Lifeline Nutrients (Chicago, IL, USA). Crisco vegetable shortening was used for all treatments (JM Smucker Co., Orrville, OH, USA). Potassium sorbate was purchased from LD Carlson Co, (Kent, OH, USA). Clabber Girl double acting baking powder was used for all treatments (Clabber Girl Co., Terre Haute, IN, USA). Ticaloid 1023 was generously donated by TIC gums (White Marsh, MD, USA). Vegetable glycerine was purchased from ChemWord (Salt Lake City, UT, USA).

### Protein analysis

Total protein of flour and experimental samples was completed by nitrogen combustion (Leco FP-2000 nitrogen analyser; Leco Corp. St. Joseph, MI, USA). A Jone's factor of 5.7 and 6.25 were used for wheat and pea flours respectively. Gluten content of wheat flour was estimated by removal of the albumin and globulin protein fractions (Smith *et al.*, 2010) and determining the protein content of the resulting flour.

### Tortilla formulation and production

The tortilla base formulation was adapted from Roberts and Cabella (2006) with modifications. Table 1 represents the base formulation. Sodium propionate and potassium were used to prevent microbial growth during storage trials (Akdogan *et al.*, 2006). A wheat tortilla made in accordance to Bello *et al.* (1991) with modifications was used as a control. The water absorption was determined to be 54%. Non-flour ingredients, with the exception of water and vital wheat gluten, were kept the same as the pea flour treatments for consistency during comparison.

Dry ingredients, except for the pre-cooked yellow pea powder were mixed to homogeneity in a 300 W Kitchen Aid electric stand mixer (Ultra Power, St Joseph, MI, USA) with paddle attachment for 2 minutes on speed setting 2. Shortening and glycerine were added to the dry ingredients and mixed to homogeneity with paddle attachment for 6 minutes at setting 2. With the paddle attachment and mixer set to speed setting 2, water was gradually added over a period of 1 minute. After water addition, the batter was

**Table 1. Tortilla formulation for optimisation experiments.**

Component	Baker's %	Batch weight
Wheat flour + yellow pea flour	100	200
Vital wheat gluten	variable	variable
Salt	1.5	3
Sodium stearyl lactylate	0.5	1
Sodium propionate	0.4	0.8
Potassium sorbate	0.4	0.8
Baking powder	2	4
Ticaloid 1023T	0.33	0.66
All-purpose shortening (crisco)	10	20
Glycerine	0.5	1
Water, tap at 32 °C (89.6 °F)	variable	variable

allowed to mix for an additional 4 minutes. After mixing the batter, the mixer remained on speed 2 with the paddle attachment. Pre-cooked yellow pea flour was gradually added over 2.5 minutes. After mixing with the paddle attachment, dough was gathered into a ball and the paddle attachment was replaced with a dough hook. Dough was mixed for 1 minute on setting 4. Dough was gathered and gently kneaded into a uniform dough ball, portioned into 40.00±0.02 g amounts, and kneaded into symmetrical balls. Balls of dough were then flattened for form a puck shape approximately 2.5 cm (1 inch) thick. Dough pucks were placed in a covered container and proofed for 15 minutes at 32.22 °C (90 °F) and 70% RH.

Dough was pressed using (TXA-SS Tortilla Press; DoughXpress, Pittsburgh, KS, USA). Top and bottom platens of the press were set at 149 °C. Tortillas were pressed for 2 seconds and the platen gap was set to 1 rotation from the thinnest setting for all treatments. Tortillas were then cooked on a griddle at 216 °C for 35 sec, flipped and cooked for an additional 35 sec at the same temperature. Tortilla pressing and cooking conditions were optimised during preliminary experiments (data not shown). After cooking, tortillas were placed on a cooling rack and tempered to room temperature for 10 min. When cooled, tortillas were placed in sealable gallon sized bags until analysis. Tortillas were stored in a dark environment at 21±2 °C until analysis.

### Experimental design and statistical analysis

Pea flour at levels 75.66, 83.83, and 92.00 g were tested as a primary factor for quality and storage trials in a 200 g flour system. Because each pea flour addition was variable in regards to its water hydration properties, water treatments and vital wheat gluten were unique for each pea flour levels. Vital wheat gluten and water treatment levels for each pea flour addition level were determined by preliminary experimentation (data not shown). Optimisation of water

and vital wheat gluten addition for each pea flour addition level was determined by tortilla diameter and opacity (Bello *et al.*, 1991; Cepeda *et al.*, 2000). For the 75.66 g pea flour treatment, 160, 170, and 180 g of water and 3.0, 3.5, and 4.0 g of vital wheat gluten were used as treatments. For the 83.83 g pea flour treatment, 180, 190, and 200 g of water and 4.0, 4.5, and 5.0 g of vital wheat gluten were used as treatments. For the 92.00 g pea flour treatment, 210, 220, and 230 g of water and 5.0, 5.5, and 6.0 g of vital wheat gluten were used as treatments. This resulted in a 3<sup>2</sup> full factorial design for each pea flour addition level. For each treatment combination, three replicates (n=3) were analysed. For each replicate, 10 tortillas were produced. tortilla diameter and opacity values were determined by taking the mean value of the 10 tortillas within the corresponding treatment replicate. Optimised tortilla formulations were then analysed for storage quality over a 20 day period in regards to toughness, extensibility, and rollability. Mean rollability and texture analysis values were taken from analysis of three tortillas. Analysis of variance was completed with a  $P < 0.05$ , using Statistical Analysis Software (SAS; SAS Institute Inc., Cary, NC, USA). A Tukey's range test was used to compare means for statistical differences in quality. For 3D graphical modelling and formulation optimisation, Design Expert (Minneapolis, MN, USA) was used.

### Tortilla analysis

For formula optimisation at each pea flour addition level, tortilla diameter and opacity was determined. For optimisation of vital wheat gluten and water, a target of 16.5 cm diameter and the highest possible opacity value was used. Tortilla diameter was determined as described by Akdogan *et al.* (2006). A mean diameter for all tortillas within a treatment replicate were reported as the representative average diameter. Opacity was determined as described by Jondiko *et al.* (2012). Again, for each treatment replicate, an average score for all tortillas was reported and statistical analysis was completed on the representative values.

For optimised formulations, each of the three pea flour treatments were analysed for toughness, extensibility, and rollability at times 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 days post production. Time zero represents 2 hours post production.

Rollability was subjectively determined by methods described by Friend *et al.* (1995). For this analysis, rollability is assessed on a scale of 1-5, where a value of 1 is impossible to roll without breakage and 5 is able to roll around a 1 cm diameter dowel without breakage or cracks. A bi-axial extensibility test measuring tortilla toughness (force required to rupture the tortilla) and extensibility (the distance to rupture the tortilla). Analysis was completed on a TA-TXplus (Stable Micro Systems Ltd., Godalming,

UK) equipped with a TA-108 fixture and tortilla probe. Analysis was conducted using the 'return to start' option and a trigger force of 5.0 g. Pre-test, test, and post-test speeds were 1.0, 1.0, and 10 mm/s, respectively. Force in grams and distance in mm were recorded at a rate of 200 pps.

### 3. Results and discussion

#### Tortilla optimisation

For optimisation of experimental tortillas, diameter and opacity were used. Optimising formulations based on physical properties of dough was deemed inappropriate. This is due to the fact that studies on the rheological properties of gelatinised pea flour containing tortillas as it correlates to end quality have yet to be completed. Furthermore, preliminary studies demonstrated that using the tortilla formulation and processes described by Roberts and Cabella (2006) produced suboptimal tortillas with rough edges and high levels of translucency. Using the aforementioned methods, a thick friable paste was produced that was difficult to handle and press. To accommodate this, gelatinised pea flour was added after gluten development, producing a smooth workable dough. With the addition of pea flour the amount of wheat flour and gluten decrease. To determine effects of decreasing gluten on tortilla quality, three levels of gluten were tested for each pea flour addition level. Water was optimised for each pea flour addition level to account for variability in ingredients. Encapsulated fumaric acid was not used in this study as it provided questionable leavening ability in preliminary studies (opacity score of ~1). Instead, a double acting baking powder was used.

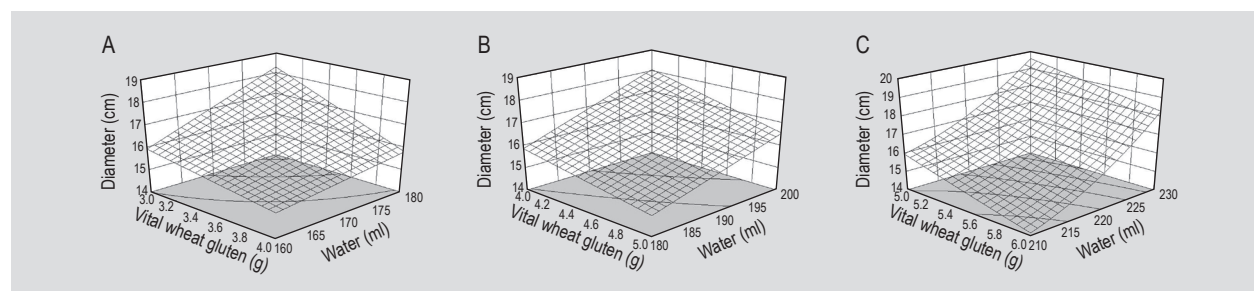
For all experiments, a wheat tortilla was used as a control for comparison. With water optimised as described by Bello *et al.* (1991), the wheat tortilla was found to have an opacity value of 4.8 and diameter of 16.5 cm. For this reason, the highest possible opacity value and a diameter of 16.5 cm were considered ideal. For all pea flour addition levels, diameters of 16.5 cm or higher could be achieved with opacity values of  $\geq 4.0$ . For all treatments, addition of

water increased diameter and decreased opacity (Table 2 and Figure 1). Conversely, addition of vital wheat gluten had a tendency to decrease tortilla diameter. Diameter values  $>16.5$  cm were observed for the highest water treatment

**Table 2. Effects of pea flour, water, and vital wheat gluten treatments on tortilla diameter and opacity.<sup>1</sup>**

Pea flour (g)	Water (g)	Vital wheat gluten (g)	Diameter (cm)	Opacity	
75.66	160	3.00	15.9 <sup>G-I</sup>	5.0 <sup>A</sup>	
		3.50	15.6 <sup>H-L</sup>	5.0 <sup>A</sup>	
		4.00	15.4 <sup>J-M</sup>	5.0 <sup>A</sup>	
	170	3.00	3.00	17.4 <sup>D</sup>	4.7 <sup>AB</sup>
			3.50	16.3 <sup>GH</sup>	4.8 <sup>AB</sup>
			4.00	15.0 <sup>M</sup>	4.7 <sup>AB</sup>
		180	3.00	18.2 <sup>C</sup>	3.0 <sup>E</sup>
			3.50	17.1 <sup>D</sup>	3.0 <sup>E</sup>
			4.00	16.2 <sup>GH</sup>	3.0 <sup>E</sup>
83.83	180	4.00	15.8 <sup>H-J</sup>	4.6 <sup>B</sup>	
		4.50	15.4 <sup>J-M</sup>	4.5 <sup>BC</sup>	
		5.00	15.1 <sup>LM</sup>	4.5 <sup>BC</sup>	
		190	4.00	17.3 <sup>D</sup>	4.5 <sup>BC</sup>
			4.50	16.3 <sup>FG</sup>	4.4 <sup>C</sup>
			5.00	15.6 <sup>I-K</sup>	4.4 <sup>C</sup>
	200	4.00	18.0 <sup>C</sup>	3.0 <sup>E</sup>	
		4.50	17.3 <sup>D</sup>	2.9 <sup>F</sup>	
		5.00	16.8 <sup>EF</sup>	2.9 <sup>F</sup>	
		210	5.00	16.0 <sup>G-I</sup>	4.4 <sup>C</sup>
			5.50	15.3 <sup>K-M</sup>	4.4 <sup>C</sup>
			6.00	14.1 <sup>N</sup>	4.4 <sup>C</sup>
	220	5.00	17.5 <sup>D</sup>	4.3 <sup>CD</sup>	
		5.50	16.3 <sup>FG</sup>	4.3 <sup>CD</sup>	
		6.00	15.9 <sup>G-J</sup>	4.2 <sup>D</sup>	
230		5.00	19.6 <sup>A</sup>	2.6 <sup>G</sup>	
		5.50	19.0 <sup>B</sup>	2.6 <sup>G</sup>	
		6.00	18.3 <sup>C</sup>	2.5 <sup>G</sup>	

<sup>1</sup> Uppercase superscript letters represent differences of means where similar letters identify no significant differences between the means ( $P < 0.05$ ).



**Figure 1. Effect of water (x axis) and vital wheat gluten (y axis) addition on tortilla diameter (vertical axis). Where (A) represents the 75.66 g pea flour treatment, (B) represents the 83.83 g pea flour treatment, and (C) represents the 92.00 g pea flour treatment.**

for each pea flour addition level. However, tortillas were thin and translucent (Table 2). Opacity was dependent on water level within each pea flour addition level. Addition of vital wheat gluten within a pea flour and water treatment had no significant effect on translucency (Table 2).

For the 75.66 and 83.83 g pea flour treatment, water addition and gluten addition had significant linear ( $P < 0.05$ ) effect on diameter (Figure 1). The water and vital wheat gluten addition levels for the 92.00 g pea flour treatment had a quadratic effect on diameter ( $P < 0.05$ ). With this, the predicted formulation optimum for each pea flour treatment level was as follows: 171.54 ml water and 3.42 g vital wheat gluten (75.66 g pea flour); 190.78 ml water and 4.48 g vital wheat gluten (83.83 g pea flour); and 219.9 ml water and 5.51 g vital wheat gluten (92.00 g pea flour). Here, the optimal formulation had a 16.5 cm diameter for all treatments. Opacity for the optimal formulations were 4.7, 4.4, and 4.3 for the 75.66 g, 83.83 and 92.00 g treatments, respectively.

Interestingly, the optimal amount of vital wheat gluten had a linear relation corresponding to the amount of pea flour addition. As the amount of pea flour increased in the formulation, the optimal level of vital wheat gluten increased. Keeping in mind that pea flour plus wheat flour represented 200 g of total flour, an increase in pea flour would result in a decrease in wheat flour. As a result, the amount of gluten originating from the wheat flour decreased in relation to the system as a whole. The wheat flour used for all treatments was found to be 11.4% protein. To determine the amount of gluten contributing to the total protein in the flour, an albumin and globulin extract was completed as described by Smith *et al.* (2010). After removing the albumins and globulins, the dried pellet was determined to contain 74% of the original protein. The 74% was then used to estimate the contribution of wheat gluten to the total protein of wheat flour. Vital wheat gluten was found have 76% protein. Using these percentages, 75.66, 83.83, and 92.00 g pea flour treatments contained 10.49, 9.80, and 9.11 g of gluten, respectively, originating from the wheat flour. By accounting for the non-protein components of the vital wheat gluten, it was found that the amount of

gluten added through the addition of vital wheat gluten was 2.64, 3.40, and 4.19 g for the optimised 75.66, 83.83, and 92.00 g pea flour treatments (Table 3). This means that the quality of the experimental tortillas was dependent on standardising the total amount of gluten in the system to 6.6% regardless of treatment (Table 3).

The average weight of the optimal tortilla formulas were 34.18 g for the 75.66 g pea flour treatment, 32.40 g for the 83.83 g pea flour treatment, and 30.4 g for the optimal 92.00 g pea flour treatment. With this, it was found that the total protein based on nitrogen combustion was 10% for the 75.66 g pea flour treatment, 11% for the 83.83 g pea flour treatment, and 11% for the optimal 92.00 g pea flour treatment on an 'as is' basis two hours post baking. On a dry basis, protein content was 16, 17, and 17%, respectively. Compared to the control wheat tortillas with 7% protein 'as is' and 9% on a dry basis, pea flour addition to tortillas can provide slightly more protein per tortilla.

### Storage stability of optimised tortilla formulations

All tortilla treatments had increasing trends in toughness values over time (Figure 2). While the wheat control had overall higher toughness values, the initial increase in toughness was more rapid than tortillas containing pea flour. This is similar to previously reported data for wheat tortillas (Akdogan *et al.*, 2006; Bello *et al.*, 1991; Cepeda *et al.*, 2000; Jondiko *et al.*, 2012). For all tortillas containing pea flour, increasing pea flour content resulted in greater toughness values for a given storage time.

At time zero, all of the pea flour treatments had similar extensibility values (Figure 3). When compared to the wheat control the experimental treatments were ~30 mm less extensible. For the duration of the storage trial, all samples decreased in extensibility and wheat had greater extensibility values for all storage times. However, all pea flour containing tortillas had a slight increase in extensibility from day 0 to day 6, followed by a gradual decrease in extensibility. This differs from the observed extensibility trends for wheat tortillas, which had a rapid decrease in extensibility from day 0 to day 6. The extensibility trends

**Table 3. Gluten content of optimal tortilla formulas.**

Pea flour (g) <sup>1</sup>	Wheat flour (g) <sup>2</sup>	Wheat flour gluten (g)	Vital wheat gluten (g)	Total gluten in tortilla formula (g)	Percentage gluten in 200 g flour
75.66	124.34	10.49	2.64	13.13	6.6%
83.83	116.17	9.80	3.40	13.20	6.6%
92.00	108.00	9.11	4.19	13.30	6.6%

<sup>1</sup> Pea flour contained 26% protein.

<sup>2</sup> Wheat flour contained 11.4% protein.

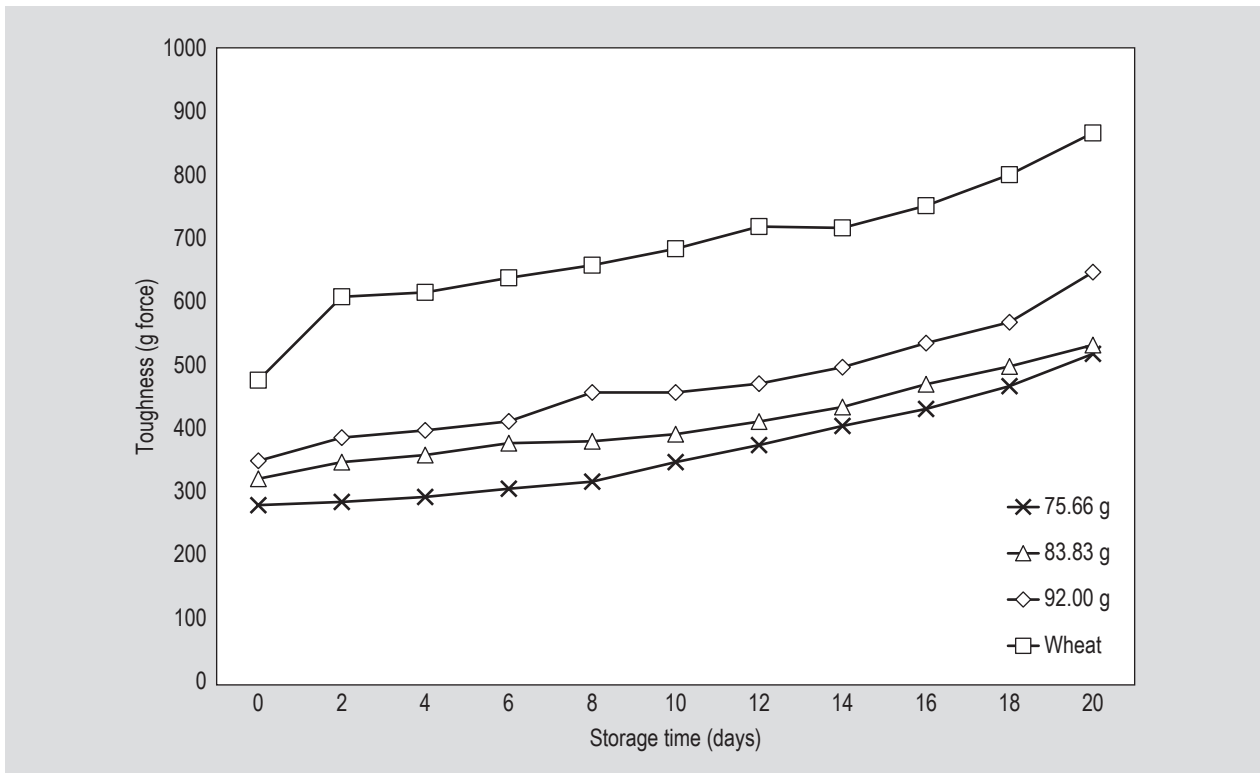


Figure 2. Toughness (g force) of tortillas made with different concentrations of pea flour compared against a wheat control over a 20-day storage period.

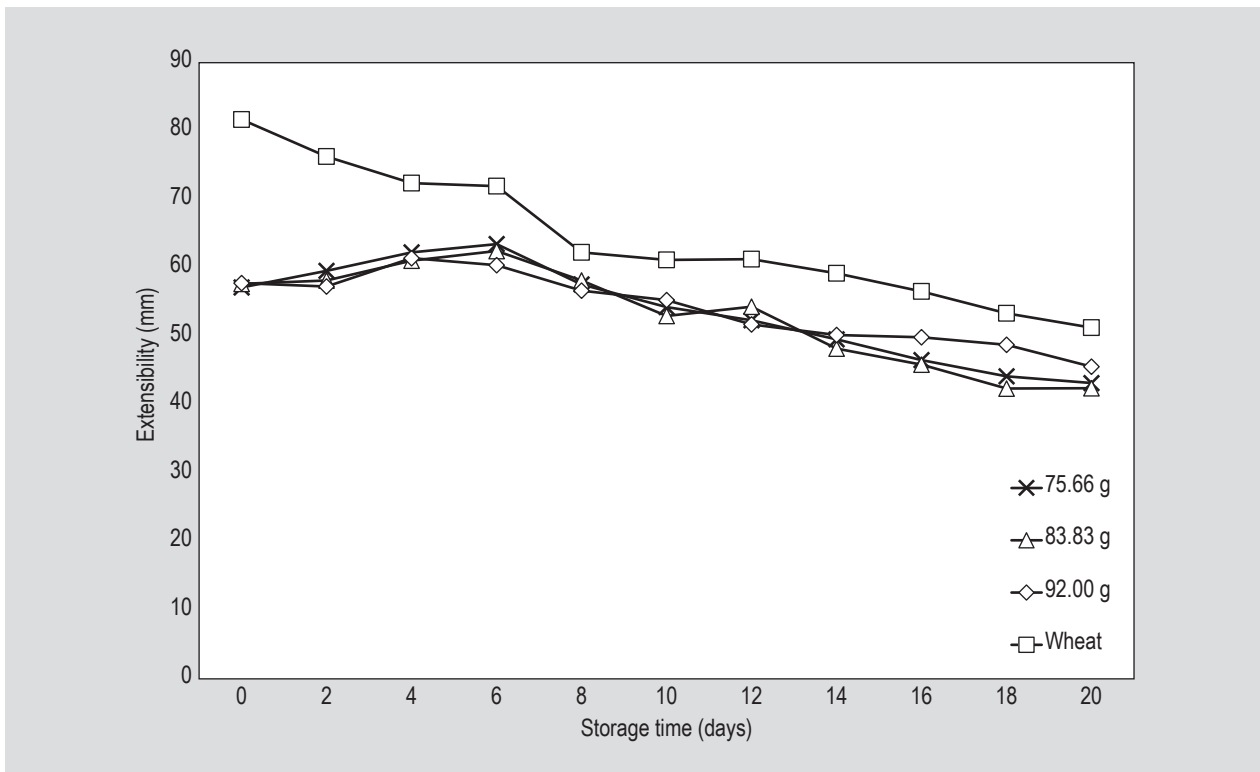


Figure 3. Extensibility (mm) of tortillas made with different concentrations of pea flour compared against a wheat control over a 20-day storage period.

observed for the wheat control are similar to data reported by others (Akdogan *et al.*, 2006; Bello *et al.*, 1991; Cepeda *et al.*, 2000; Jondiko *et al.*, 2012). It is unknown why the optimised pea flour containing tortillas increased in extensibility for the duration of the first 6 days of the storage trial. Furthermore, the increase in extensibility does not correspond to an increase in rollability or toughness (Figure 2 and 4). Possible explanations for this phenomenon are moisture migration, and/or interaction between ingredients.

Tortillas were rated on a scale from 1-5, where 1 was an easily breakable tortillas and a score of 5 represented a tortilla that was easy to roll without cracking or breaking. Initially, all tortillas had a rollability of 5 (Figure 4). Over the 20 day storage trial, all tortilla treatments and control had similar rollability values and trends, where final rollability values ranged from ~2.7 (wheat) to ~3.4 (92.00 g pea flour treatment). It should be noted that when cracks occurred on the control wheat tortilla, they were generally prominent with some flaking of the outer tortilla layers. Dissimilarly, when the pea flour treatments cracked during rollability analysis, small fissures were created on the outside layer of the tortilla with no flaking.

Addition of pea flour to tortillas decreased the extent of change occurring to the tortillas overtime. While wheat

had greater overall toughness, extensibility, and rollability values, the amount of change occurring over a 20 day storage trial was greater than tortillas containing pea flour (Figure 2 and 4). This means that the addition of pre-cooked pea flour to tortillas can improve storage stability of tortillas.

#### 4. Conclusions

Previous studies demonstrated that pre-gelatinised pea flour can be added to tortillas without negatively impacting sensory characteristics. High quality tortillas, with similar diameters and opacity values to wheat tortillas can be made with the addition of 75.66, 83.83, and 92.00 g of pre-cooked pea flour. Protein content for pea flour tortillas was slightly higher than the wheat control on an 'as is' basis and 7-8% higher on a dry basis. Tortillas containing pre-cooked pea flour can improve nutritional properties and storage stability of tortillas. Future work should be completed to determine the optimal leavening system for tortillas containing pre-cooked pea flour.

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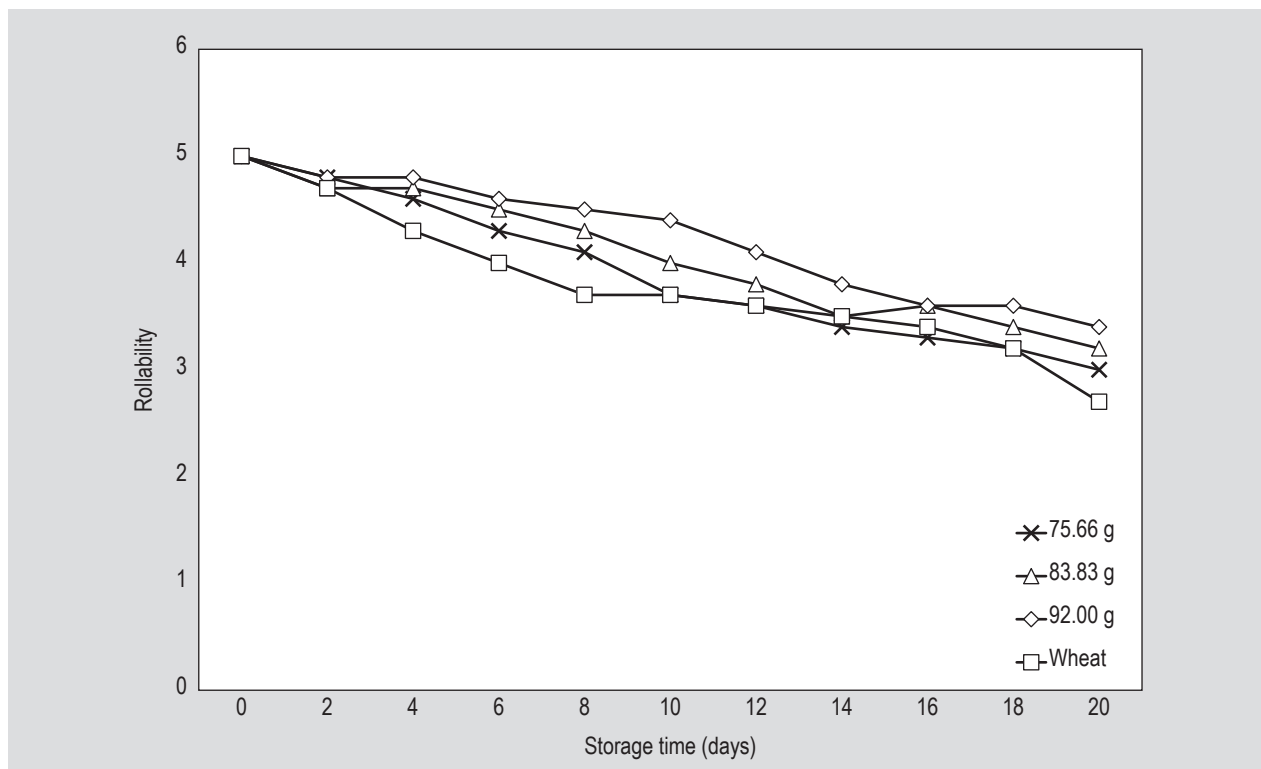


Figure 4. Rollability scores of tortillas made with different concentrations of pea flour compared against a wheat control over a 20-day storage period.

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