Incorporation of Selected Pulse Flours into Dried Asian White Salted Noodles

By

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ABSTRACT

This study was undertaken to determine the suitability of pulse flours in dried Asian white salted noodles and their effect on noodle quality and nutritional characteristics. Whole yellow peas, green lentils and navy beans were milled into flours of two different particle sizes, and incorporated into noodles at 25, 30 and 35% with Canadian Western Red Spring wheat flour. Compositional and functional analysis was performed on all flours. Pulse type, blend level and flour particle size all had an effect on noodle quality as determined by instrumental and sensory methods. The addition of pulse flours improved the nutritional profile of the noodles by increasing fibre and protein content. Dried and cooked noodle colour, as well as optimal cooking times, were affected by the addition of pulse flours. Differences in firmness were observed using instrumental texture analysis but were not detected in sensory analysis, however the sensory panel did detect differences in other textural and flavour characteristics.

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LIST OF ABBREVIATIONS

AACC	American Association of Cereal Chemistry
AAFC	Agriculture and Agri-Food Canada
ANOVA	Analysis of Variance
AOAC	Association of Analytical Communities
CFIA	Canadian Food Inspection Agency
CIGI	Canadian International Grains Institute
CWRS	Canadian Western Red Spring
OCT	Optimum Cooking Time
RCF	Relative Centrifugal Force
RPM	Rotations per Minute
RVA	Rapid Visco Analyzer
RVU	Rapid Visco Units
USDA	United States Department of Agriculture
WAC	Water Absorption Capacity

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CHAPTER 1: INTRODUCTION

Pulses, also known as grain legumes, is the term used to describe the edible seeds of legumes such as dry peas, dry beans, lentils and chickpeas (Pulse Canada, 2011). Over the last two decades, the Canadian pulse industry has grown to be the world's top producer of dried peas and lentils as well as a producer of beans and chickpeas (Agriculture and Agri-Food Canada (AAFC), 2009). Of all the pulses grown in Canada, over 75% are exported, with the majority going to India, China, Bangladesh and Turkey (AAFC, 2009) as whole seeds. Although there is a current demand for pulses as whole seeds, one way to increase domestic consumption and thereby increase demand, is to incorporate pulse flours or fractions into existing food products and formulations by using them as an ingredient.

Incorporating pulse flours into food items is not a new concept. Research exists that examines the addition of pulses to baked goods such as breads (Dalgetty & Baik, 2006; Sadowska et al, 1999), cookies (Hoojjat & Zabik, 1984), muffins (Cady et al, 1987), and cakes (Gomez et al, 2008) as well as pasta (Bahnassey & Khan, 1986; Cabello et al, 1992), snack products (Hardacre et al, 2006) and meat products (Serdaroglu et al, 2005, Modi et al, 2003). The research surrounding the use of pulses as ingredients is not limited to the food products and research listed above. As consumer demands and wants change, new food products and formulations will evolve to satisfy consumers.

Pulse flours offer nutritional benefits that set them apart from other ingredients. They are high in total dietary fibre and low in fat. They are high in protein, and contain the amino acid lysine, which when combined with wheat, contributes to a complete protein. In 2011, Health Canada made the recommendation that Canadians consume beans, lentils and tofu often. Over the last decade, nutrition has become health oriented (Leterme, 2002) and several health organizations are promoting a diet rich in pulses because of their health benefits. The Canadian Diabetes Association, Diabetes UK, the World Cancer Research Fund, American Institute of Cancer Research, Harvard University of Public Health, the American Heart Association and the Heart Information Network have all endorsed the consumption of pulses in reducing the risk of disease (Pulse Canada, 2010; Leterme, 2002).

Asian white salted noodles are widely consumed in many parts of the world. Their current formulation of refined wheat flour, salt (NaCl) and water is low in nutritional value. The addition of pulse flours into the formulation would greatly improve the nutritional properties of the noodles and could potentially offer some favourable functional characteristics. The objective of this research was to produce Asian white salted noodles using a blend of selected pulse flours with wheat flour to create a noodle with nutritional benefits without negatively affecting colour and texture. Three different pulse flours, milled to two different particle sizes were added at three different levels to determine the suitability of adding pulse flours to white Asian salted noodles. In addition to the main objective of making Asian white salted noodles with pulse flours, specific objectives of this study are to:

1. Develop a processing method for incorporating pulse flours at different blend levels into Asian salted noodles.

2. Evaluate noodle quality, during processing and in the final product, to determine how the incorporation of pulse flours at various blend levels affects noodle quality using both instrumental and sensory methods.
3. Determine the effects of flour particle size on noodle quality characteristics by using both coarse and fine pulse flours.
4. Evaluate the composition of the pulse and wheat flours and dried noodles to determine how the incorporation of pulse flours changes the composition of the end noodle product.

CHAPTER 2: LITERATURE REVIEW

2.1. Canadian Pulse Production

Canadian production of pulses increased from 752,500 tonnes in 1991 to 5.2 million tonnes in 2009 with approximately 75% of yields being exported (AAFC, 2009). Canada is the top producer of dried peas and lentils, and is in the top ten producers of beans and chickpeas (AAFC, 2009). Growing regions are located in Alberta, Saskatchewan, Manitoba, Ontario and Quebec (Pulse Canada, 2007).

2.1.1. Dry Peas

In 2009, dry peas represented 65% of total pulse production in Canada (AAFC, 2009). The majority of dry peas (43%) were exported to India followed by China (12%) and Bangladesh (9%) (AAFC, 2009). The majority of peas grown in Canada are yellow and green varieties (AAFC, 2009) and are grown predominately in Saskatchewan and Alberta with some production in Manitoba (Pulse Canada, 2007). Dried peas are commonly used as whole or split seeds, flours, and fractions such as protein, fibre and starch (Pulse Canada, 2007).

2.1.2. Lentils

Red and green lentils are the second largest grown pulse crop in Canada and comprised 29% of total pulse production in 2009 (AAFC, 2009). Lentil exports increased by 292% between 2006 and 2009 with Turkey being the largest importer (AAFC, 2009). Saskatchewan is the major producer of Canadian lentils with some production in Alberta and Manitoba (Pulse Canada, 2007). Lentils are used as whole or split seeds, and are also available canned, flaked and as flour (Pulse Canada, 2007).

2.1.3. Dry Beans

White navy beans represent the largest bean crop grown in Canada and made up 35% of total bean production in 2009 (AAFC, 2009). The United Kingdom, the United States and Italy are the top importers of Canadian beans (AAFC, 2009). Other varieties of beans commonly grown in Canada include pinto, kidney, black, cranberry, adzuki and pink beans (Pulse Canada, 2007). Dry beans make up 4% of total pulse production and are mostly grown in Ontario, Quebec and Manitoba with some acreage in Saskatchewan and Alberta (Pulse Canada, 2007). Dry beans are commonly available both canned or in dry form, as flour, as well as in processed food items such as soups (Pulse Canada, 2007).

2.2. Composition of Pulses

Pulses are a highly nutritious food. They are high in fibre and protein, low in fat and sodium and are a good source of vitamins and minerals (Pulse Canada, 2010). The nutritional composition of selected pulses can be seen in Table 1.

Table 1: Nutritional Composition of Selected Canadian Pulses (100g/dry).

	Whole Yellow Peas	Whole Green Lentils	Whole Navy Beans	References
Total Dietary Fibre (g)	14-26	18-20	23-32	Tosh & Yada (2010)
Insoluble Fibre (g)	10-15	11-17	20-28	Tosh & Yada (2010)
Soluble Fibre (g)	2-9	2-7	3-6	Tosh & Yada (2010)
Protein (g)	23.3	25.8	25.1	Pulse Canada (2010)
Fat (g)	1.2	1.1	1.5	Pulse Canada (2010)
Iron (mg)	5.6	7.6	7.9	Wang & Daun (2004)
Potassium (mg)	1047	965	1705	Wang & Daun (2004)
Zinc (mg)	3.9	3.9	3.4	Wang & Daun (2004)
Copper (mg)	0.7	1.0	1.1	Wang & Daun (2004)
Thiamine (mg)	0.51	0.29	0.58	Wang & Daun (2004)
Riboflavin (mg)	0.18	0.33	0.16	Wang & Daun (2004)
Niacin (mg)	1.55	2.57	1.31	Wang & Daun (2004)
Folate (mcg)	33.8	180	108	Pulse Canada (2010)

2.2.1 Dietary Fibre

Pulses contain soluble and insoluble fibres, which are found in both the hull and the cotyledon. The amounts and specific types of fibres present depend on the pulse type; however, they are mainly composed of cellulose, hemicellulose and pectins (Tosh & Yada, 2009). Soluble and insoluble fibre contents of selected pulses can be seen in Table 1. A diet high in dietary fibre has been linked to a reduced risk of heart disease, diabetes, obesity and some forms of cancer (Marlett et al, 2002).

2.2.2. Protein

Pulses are a good source of vegetable protein and are high in the amino acids leucine, aspartic acid, glutamic acid, arginine and lysine but deficient in tryptophan, methionine and cysteine (Boye et al, 2010). Cereal grains, including wheat, are deficient in the amino acid lysine. By supplementing food products that traditionally use 100% wheat with pulse flours, a more complete protein is created (Iqbal et al, 2006). The proteins in pulses are storage proteins and are made up of globulins, which are salt soluble, and albumins, which are water soluble (Boye et al, 2010). Protein composition can affect functional properties such as water or fat absorption capacity, solubility or foaming characteristics of pulses when they are used as an ingredient (Boye et al, 2010).

2.2.3. Fat

Pulses are naturally low in fat. The pulses with the highest fat content are chickpeas which contain approximately 5-6% (Wang & Daun, 2004) whereas peas, lentils and beans are between 1-2% (Table 1).

2.2.4. Carbohydrates

Starch is the major carbohydrate in pulses and, depending on the pulse, consists of between 22-45% of total carbohydrates (Hoover & Sosulski, 1991). The starches in pulse seeds are comprised of amylose and amylopectin. Amylose makes up approximately 25% of the total starch, and is made up of linear chains of α-D-glucopyranose residues linked by (1→4) bonds while amylopectin is made up of linear chains of (1→4) α-D-glucose residues bonded with (1→6) α-linkages (Hoover & Sosulski, 1991). The differences in amylose content of peas, lentils and beans as reported by Wang & Daun (2004) can be seen in Table 2.

Table 2: Amylose Content of Selected Pulses

Pulse Type	Amylose (%)
Whole Yellow Pea	25.6
Whole Green Lentil	25.4
Whole Navy Bean	24.6

2.2.5. Vitamins and Minerals

Pulses are a good source of many vitamins and minerals. They contain iron, zinc and copper, which are essential micronutrients and pulses are also good sources of thiamine, riboflavin and niacin (Campos-Vega et al, 2010). Selected vitamin and mineral contents can be seen in Table 1.

2.2.6. Anti-nutritional Factors

Anti-nutritional factors including, but not limited to, trypsin inhibitors, phytates and phenolic compounds exist in legumes and when consumed, can have adverse health effects. Trypsin inhibitors reduce protein digestibility (Lajolo & Genovese, 2002), phytic acid diminishes mineral bioavailability (Sandberg, 2002) and phenolic compounds have been shown to do both (Chung et al, 1998; Sandberg, 2002). Despite the negative effects of anti-nutritional factors, there is evidence to suggest that they do offer some beneficial health benefits such as protecting against certain cancers, diabetes, cardiovascular disease, osteoporosis and hypertension (Carbonaro, 2011). Therefore, the elimination of these anti-nutritional factors from the diet is not encouraged, although, further research needs to be done to determine the threshold levels of anti-nutritional factors (Carbonaro, 2011).

2.3. Noodles

2.3.1. Introduction

Noodles are a staple food in many parts of Asia. Noodles made from wheat flour are most common, however, noodles made from rice flour, buckwheat flour, and starches such as mung bean, tapioca, sweet potato, sago, wheat, rice and corn are also available (Hou, 2010). The consumption of noodles has been steadily increasing not only in Asia but in other parts of the world (Hou et al, 2010) making noodles a popular food product. Noodles are categorized based on the ingredients used, processing method and/or the size of the strands.

2.3.2. Ingredients and Characteristics

Noodles are commonly made with refined wheat flour, salt (NaCl) and water. The type of salt selected has an effect on the colour, flavour and texture of the final noodle product. Wheat noodles are made using either regular salt (NaCl) or alkaline salts (Na_2CO_3 and/or K_2CO_3) (Fu, 2008). Noodles made with NaCl salts are referred to as white salted noodles, although some geographical regions prefer a creamier colour that is more off-white (Crosbie & Ross, 2004).

White salted noodles are produced from wheat flour, water and 2-8% salt (NaCl) and are available fresh, dried or boiled (Fu, 2008). They should be bright in colour, have good textural and flavour characteristics and have a long shelf life (Fu, 2008). The desired texture is dependent on the region of consumption. For yellow alkaline noodles, the amount of salt depends on the final product. For fresh noodles, 1.0-1.5% alkaline salts are added, 0.3-0.5% for steamed and 0.3-1.0% for partially boiled (Fu, 2008). The addition of alkaline salts positively affects noodle brightness and yellowness, which is desirable in some regions (Crosbie & Ross, 2004). Alkaline salts can also be added as a quality improver or dough conditioner at low levels to improve the texture without imparting a strong flavour (Fu, 2008). Of these two types of noodles, white salted are more commonly consumed than yellow alkaline noodles in Asia (Fu, 2008).

For both yellow alkaline and white salted noodles, wheat with a high protein content and strong gluten strength is desirable as it has a positive effect on the texture of noodles and imparts chewiness, which is desirable (Chen & Yang, 2010). Gluten strength is critical during sheeting, and using wheat with low gluten strength results in processing difficulties. Wheat with low ash values is desirable as it is less likely to cause noodle discolouration and/or speckiness (Chen & Yang, 2010).

2.3.3. Noodle Processing

2.3.3.1. Mixing

Traditionally, wheat noodles were made by hand through stretching or sheeting and then hand cutting (Hou et al, 2010). Commercially, wheat flour noodles are made by first mixing flour, salt, and water to combine the ingredients and hydrate the flour particles (Fu, 2008). The type of mixer used depends on the ingredients and the desired noodle characteristics. A slow-speed mixer used with high-water dough formulas mimics the motions of hand mixing allowing for optimal gluten development (Hou et al, 2010). A high speed mixer sprays the salt solution on the flour allowing for a larger contact area which results in instant and even hydration of dough particles (Hou et al, 2010). A vacuum mixer allows for more water to be added to the dough mixture and it encourages gluten development during sheeting (Wu et al, 1998). The addition of other ingredients such as starch, gums, food colours or preservatives can be added during mixing (Fu, 2008).

Maintaining an optimal temperature during mixing is important for end-product quality and is achieved by regulating water temperature. Hot water can denature proteins and gelatinize starch, while cold water slows down dough hydration and gluten development which results in a need for longer mixing times (Hou et al, 2010). An optimal dough temperature is reported to be between 25 and 30°C (Hou et al, 2010).

After mixing, the dough crumbs are allowed to rest before being sheeted. Resting the result in a smoother and less streaky dough sheet due to increased water penetration (Hou et al, 2010).

2.3.3.2. Sheeting, Compounding and Cutting

After resting, the dough crumbs are fed between two rolls where they pass through to form a dough sheet. The resulting dough sheet generally has a rough surface and lacks uniformity so it is folded, or compounded, and then allowed to pass through the rolls a second time (Fu, 2008). After the second pass, the dough sheet is allowed to rest for a specified time in order to relax the gluten structure (Fu, 2008).

Upon completion of resting, the dough sheet is then passed through a series of moving rolls which are gradually increasing in speed and decreasing in gap width, thereby gradually reducing the thickness of the dough sheet (Hou et al, 2010). A gradual decrease is necessary as the gluten structure may be damaged during sheeting if the reduction in sheet thickness exceeds 30% (Crosbie & Ross, 2004). The temperature of the rolls is critical as changes in temperature will have an effect on dough sheet elasticity (Crosbie & Ross, 2004). The sheeting process also aids in developing the gluten network (Fu, 2008). Once the process of sheeting is completed, the noodles are ready to be cut. The dough sheet is cut into noodles using a cutter or slitter (Hou et al, 2010) and are cut in the direction that the dough was sheeted (Fu, 2008).The desired noodle width determines which cutter is used. Most noodles that are cut into strands that are rectangular, square or round in shape (Fu, 2008). This method of mixing, resting, sheeting, compounding, sheeting/reduction, and cutting is constant for all machine made noodles with only minor adjustments being made by processors (Fu, 2008).

2.3.3.3. Drying

Depending on the noodle type, drying is the final stage before packaging. Traditionally, noodles were dried outside. Commercially, noodles are dried using a three step process which is carried out in a chamber with controlled temperature, humidity and air flow (Hou et al, 2010). All of these factors are dependent on the type and quantity of noodle being processed. The initial stage of drying takes approximately 30-60 minutes at a low temperature (15-25°C) using dry air with approximately 60% humidity (Hou et al, 2010). This initial drying step is crucial to dry the noodles enough to avoid stretching during the remainder of the drying process (Hou et al, 2010). Stretching can cause the noodles to break and fall from the drying rods. Noodles have to be dried gradually to ensure that the interior of the noodles dries properly to avoid noodle checking (Hou et al, 2010).

The second stage of drying takes approximately 6 hours and is the process of applying warm (~40°C) and humid (70-80% RH) air to allow the noodles to reach a moisture content of 1-2% above the target moisture of 10-12% (Hou et al, 2010). These conditions encourage the migration of moisture from the core of the noodle to the outside surface (Hou et al, 2010). Quality problems, such as cracking, warping, splitting and over-elongation can occur if this main drying process is rushed or takes too long (Fu, 2008).

The final stage of drying is designed to cool the noodles to room temperature which makes them ready for any final cutting and packaging processes (Hou et al, 2010). Temperatures are reduced by 0.5°C/min to avoid noodle checking (Hou et al, 2010). If the noodles are not cooled to room temperature before packaging, moisture condensation can occur and shelf-life will be reduced (Hou et al, 2010). Problems at any of the three stages of drying can result in noodle twisting, stretching. checking or noodle tip flaring, as well as discolouration (Hou et al, 2010).

Other drying methods that are used include low and high temperature drying (Hou et al, 2010), as well as hanging noodles outside to dry in tolerable climates (Fu, 2008), although the three stage method described above is the most common.

2.3.4. Noodle Types

According to Fu (2008), there are three major types of white salted noodles – fresh, dried, and boiled. These and several other types of noodles are produced and are listed in Table 3. Salted noodles can further be classified by the size of the noodle strands and are summarized in Table 4.

Table 3: Summary of Common Noodle Types

Processing Method	Characteristics
Fresh Raw	Raw wet noodles. Processing is complete after cutting. Moisture content of fresh noodles ranges from 32-40% and has a shelf life of one to several days.
Dried	Noodles that are dried after cutting. Moisture content of dried noodles is between 10 and 14% and they have a shelf life of 1-2 years.
Steamed	Fresh noodles are partially cooked with steam before they are sold. Steamed noodles are available as low moisture and high moisture varieties.
Steamed & Deep Fried Instant	Noodles are partially cooked by steaming and then cooked and dehydrated through deep frying. Noodles are immediately cooled and then packaged. These noodles have an oil content of 15-22%.
Steamed & Hot Air Dried	Noodles are partially cooked by steaming and then go through a continuous dryer with a temperature above 80°C. The moisture content is less than 12% and has a shelf life of approximately 1 year.
Low Moisture Steamed	Contain less that 35% moisture and are made by steaming for 10 minutes with dry steam before cooling and packaging.
High Moisture Steamed	Contain between 55-65% moisture and are made by steaming for 4-6 minutes, steeping in hot water and then cooling. They are mixed with vegetable oil before packaging.
Boiled	Fresh noodles that are precooked in boiling water, steeped in cold water, and then packaged. Boiled noodles can be both partially boiled and fully boiled.
Parboiled Alkaline	Are partially boiled alkaline noodles that are cooked for 0.5-1.5 minutes and then packaged. These are commonly known as Hokkien noodles.
Sterilized boiled or Long Life (LL)	Noodles that have been fully boiled and are then pasteurized with heat. Before packaging they are dipped in dilute acidic water and then steam pasteurized. They have a shelf life of 5-8 months.
Frozen boiled	Noodles that are boiled and then frozen using quick freezing technology and have a shelf life of up to 1 year. They can be cooked quickly from frozen state.
Freeze Dried	Freeze dried noodles dry because of the sublimation of ice crystals directly to water vapour. Freeze drying is an expensive and slow process but freeze dried noodles are convenient for stores to carry.
Non-wheat	Noodles made with but not limited to ingredients such as starch, buckwheat and rice.

(Fu, 2008; Hou et al, 2010).

Table 4: Noodle Classification Based on Noodle Strand Width

Name	Characteristics	Width (mm)
So- men	Very Thin	1.0 - 1.2
Hiya-mugi	Thin	1.3 – 1.7
Udon	Standard	2.0 – 3.9
Hira-men	Flat	5.0 – 7.5

(Fu, 2008).

2.3.5. Quality Evaluation

Many of the parameters that are evaluated to determine noodle quality are dependent on the region or area of consumption. What may be considered ideal in China, may not be desirable in Japan. A dish that is prepared a certain way in Northern Asia may be prepared differently in Southern parts of Asia. There is agreement that the important quality characteristics in noodles are colour, texture, flavour and shelf life (Fu, 2008), however, the specifics of these parameters may vary.

2.4. Addition of Pulse Flours in Different Food Applications

2.4.1. Introduction

Pulse flours are produced from pulse seeds that have been ground or milled and then passed though one or more screens to produce a flour of uniform particle size (Wood & Malcolmson, 2011). There are different milling methods that can be used to make flours from both whole and dehulled seeds that will produce flours of different granulations. Research has been done on the addition of pulse flours to a variety of food products that examine the effects on functional properties, nutritional benefits, and overall consumer acceptability. Pulse flours have been successfully added to a variety of meat products (Serdaroglu et al, 2005, Modi et al, 2003), baked goods such as breads (Dalgetty & Baik, 2006; Sadowska et al, 1999), cookies (Hoojjat & Zabik, 1984), tortillas (Anton et al, 2008), muffins (Cady et al, 1987), snack products (Hardacre et al, 2006) and pasta (Bahnassey & Khan, 1986; Cabello et al, 1992). Below is a brief summary that illustrates the effects that added pulse flours have on some of these food applications. While there is evidence to support the use of pulse flours in various food applications, there is little research available on the use of pulse flours in Asian noodles.

2.4.2. Meat Products

The addition of pulse flours into meat products has been successful because of the positive functional characteristics that are attributed to pulse flours . Serdaroglu et al (2005) and Modi et al (2003) discovered adding pulse flours at 10 and 8% respectively could be successfully incorporated into meat products and used as fillers, binders or extenders without adding unwanted fat. Verma et al (1984) were successful in adding pulse flours (up to 40%) into sausage products, which in turn created a more affordable product for consumers. The addition of pulse flours to meat products is appealing to consumers as it does not add fat, increases the nutritional content and can provide functional attributes, such as binding properties, that contribute to consumer acceptability.

2.4.3. Baked Goods

The addition of pulse flours into baked goods has been studied more than any other food application. McConnell et al (1974), D'Appolonia (1977; 1978) and Fleming & Sosulski (1977; 1978) were some of the first researchers to look at the addition of pulse flours and/or fractions in breads while research in this area still continues. Sathe et al (1981) reported that using bean flour in breads yielded acceptable results, however, strong flavours were observed when flour incorporation was greater than 20%. Wang et al (2002) added pea fibre (3%) to bread and increased the dietary fibre while maintaining acceptable sensory scores. Dalgetty and Baik (2006) found that adding 5% hulls or insoluble fibres or 3% soluble fibres to bread increased dietary fibre while improving moistness without compromising other quality parameters.

Quick breads and cakes have also been successfully reformulated to include pulse flours or fractions. Dryer et al (1982) added bean flours to banana bread at levels of up to 50% and observed decreased volumes and darker colour but had a successful product when using 35% navy bean flour. Gomez et al (2008) were able to add chickpea flours to sponge and layer cakes and reported that whole chickpea flour posed more problems than dehulled chickpea flour. It was observed that pulse flours affected the cake volume, firmness, cohesiveness and gumminess; therefore, attention needs to be paid to substitution levels and other flour attributes (whole vs. dehulled). The studies listed above are only a fraction of the studies that have been done utilizing pulse flours in baked goods. All results indicate that pulse flours have an effect on the functional and nutritional properties of baked goods. Proper attention needs to be given to blend levels, pulse type and specific flour characteristics to avoid functional problems and problems with consumer acceptability.

2.4.4. Pasta

Despite the limited research available on the incorporation of pulse flours into noodles, there have been a number of studies done on the addition of pulse flours to pasta products. Bahnassey and Khan (1986) were able to fortify spaghetti with up to 10% roasted and non-roasted pulse flours to increase protein content. Cabello et al (1992) added 15% navy bean flour to microwavable pasta and like Bahnassey and Khan (1986) saw an improvement in nutritional value. They also observed the pasta containing pulse flours absorbed more water during cooking and had a softer texture than pasta made with 100% semolina. Zhao et al (2005) conducted a sensory panel in which panelists' acceptance of pastas with pulse flours decreased as the blend level increased. Sabanis et al (2006) added chickpea flour to lasagna noodles and at low levels of incorporation (5-10%) saw improved texture and nutritional values, but like previous research, encountered problems with texture and sensory scores when higher levels were used. Petitot et al (2010) observed that when using high levels (35%) of pulse flours in pasta, adjustments had to be made to the product formulation and concluded that lower hydration levels and a higher mixing speed were required.

Similar to Asian noodles, flavour, texture and appearance are all important quality parameters used to evaluate pasta. The researchers listed above all saw limitations in the quantities of pulse flour that could be included due to issues with texture and flavour as well as adjustments that had to be made in processing. These issues arose regardless of pulse type. Despite the above limitations, pasta products supplemented with pulse flours are currently available, such as Barilla Plus in the United States.

2.4.5. Noodles

As previously mentioned, extensive research has been done looking at the incorporation of pulse flours into specific food applications such as baked products and pastas. Despite the successful addition of pulse flours into these food products, the amount of research done on the inclusion of pulse flours in dried white salted noodles is limited. There is research on the use of pulse starches as these products are commercially available. Mung bean and yellow pea starch are commonly used in noodles that are commercially available worldwide (Prabhavat, 1988). These noodles are made with purified starch that has been extracted from the pulse seed (Fu, 2008). Other ingredients that have been incorporated in white salted noodles include potato and sweet potato starch (Chen et al, 2003), rice starch (Sandhu & Kaur, 2010), wheat bran (Chen et al, 2011) and purple yam flour (Li et al, 2011). The use of pulse flours in dried white salted noodles and the effects on processing and quality parameters are not well known. When producing white salted noodles, processing properties, appearance, and colour are the most important criteria used to evaluate the end product (Fu, 2008). It is crucial to begin with high quality raw materials to ensure that the end product will meet or exceed quality standards.

All of the parameters used to measure the quality of noodles are important, it is significant to note that with the addition of pulse flours, colour will be one of the most obvious characteristics affected because of the differences in colour between wheat kernels and pulse seeds. Colour and overall appearance are crucial as they can be determining factors in deciding whether or not a consumer will consider buying or eating a certain noodle product. For white salted noodles, a white or creamy white colour is considered highly desirable, depending on the region of consumption (Fu, 2008). It is apparent that the addition of pulse flours will change the visual appearance and will affect the colour of the noodles, regardless of processing. Pulses range in a variety of colours, therefore, specific pulse types may be more suitable for white salted noodles than others.

Changes in colour have been well documented in the few studies examining the incorporation of pulse flours into various noodle products. A slight decrease in L* values (brightness) was observed by Chompreeda et al (1988) with the incorporation of cowpea flour in Chinese type noodles and by Han et al (2006) who added lentil, pea, and chickpea flours to white salted noodles. Hung & Nithianandan (1993) observed an increase in b* values (yellowness) when chickpea and lupin flours were added to unsalted white noodles and reported that as blend levels increased, b* values continued to increase. The same increase in b* values was observed by Lee et al (1998) with the incorporation of garbanzo bean (chickpea) flour as well as an increase in a* (redness) values. Like the other researchers, Jeffers et al (1979) noticed an increase in the yellowness of noodles into which raw and cooked commercial yellow pea flours had been incorporated and determined that regardless of the flour treatment, cooking the noodles improved the colour.

Another important parameter related to the quality of white salted noodles is texture. Like colour, the desired textural characteristics depend on the region in which the noodles are being consumed. Textural properties that are considered desirable in noodles in Japan and Korea are soft, smooth, and elastic (Crosbie & Ross, 2004) while in China the preferred texture is firm, elastic and chewy (Huang, 1996). Although the protein content of pulse flours is higher than wheat, pulse flours lack gluten, the protein found in wheat. Adequate gluten strength and extensibility is essential in noodle flours for successful sheeting and drying (Fu, 2008), which are directly related to the firmness and texture of white salted noodles. In order to achieve success during processing, pulse flours need to be blended with a high protein content wheat flour. Texture is commonly measured instrumentally using texture analyzers as well as by panelists during sensory analysis.

Previous research has found that the addition of pulse flours does alter the textural properties of white salted noodles. Lee et al (1998) found that when garbanzo bean (chickpea) flour was incorporated, hardness, springiness, cohesiveness, gumminess and chewiness all decreased. Subsequently, they found that as the levels of pulse flours increased, the thickness of the noodles decreased. Decreased firmness values were also reported by Chompreeda et al (1988) and Han et al (2006), where an inverse relationship was observed in regards to firmness and the levels of pulse flours incorporated into the white salted noodles. In some cases, additives can be used to improve the texture of noodles that have been compromised due to the reduced gluten content. Transglutaminase is an enzyme that catalyzes acyl-transfer reactions and results in covalent cross linking between proteins (Takacs et al, 2007). A bond is formed between lysine and glutamine residues, without compromising the nutritional value of lysine thus improving the structure of the end noodle product (Takacs et al, 2007).

As well as changing the appearance and texture of white salted noodles, the incorporation of pulse flours also changes the composition and nutritional profile. Chompreeda et al (1988), Hung & Nithianandan (1993) and Lee et al (1998), all observed that as the quantities of pulse flour increased, the protein content of the noodles increased. As previously mentioned, pulse are rich in the amino acid lysine, which wheat lacks; therefore, noodles produced from a blend of wheat and pulse flours noodles offer a more complete protein. As well as increasing the protein content, incorporating pulse flours can increase the dietary fibre content of white salted noodles. Hung & Nithianandan (1993) indicated that total dietary fibre was increased by three to five times when supplemented with chickpea flour and eight to ten times with lupin flour. The amount of dietary fibre varies according to pulse type, therefore, the increase in dietary fibre of white salted noodles will depend on the pulse flour that is added and the level of incorporation.

Although pulse flours add beneficial nutritional components to white salted noodles, pulse flours also contain several anti-nutritional factors including phenolics, phytic acid and trypsin inhibitors. Despite the abundance of research available that documents the anti-nutritional factors that are present in pulses, not a lot is known about their presence in noodles that have been formulated with pulse flours. Soaking, dehulling, cooking, dry heat, fermentation, germination (Egounlety & Aworh, 2003; Marquez et al, 1998) are all common methods used to reduce or eliminate anti-nutritional factors from pulses and pulse flours. Further research is needed to determine levels of anti-nutritional factors in white salted noodles supplemented with pulse flours.

In order to successfully add pulse flours to white salted noodles, certain blend levels need to be incorporated. If levels are too low, there will be no added nutritional benefits and if levels are too high, problems can arise in processing and during sensory analysis. As indicated above, different blend levels will affect colour and appearance, texture and composition as well as flavour and various dough properties. Existing research indicates that pulse flours can be successfully incorporated into noodles at blends between 5 and 30% (Jeffers et al, 1979; Chompreeda et al, 1988; Hung & Nithianandan, 1993; Lee et al, 1998; Han et al, 2006). Noodles containing more than 30% pulse flours tend to exhibit strong flavours and aromas.

In addition to blend levels, particle size is another factor that has been studied in order to determine the differences between coarse and fine particles and their suitability in white salted noodles. When producing noodles with 100% wheat flour, fine particles are desired as they allow for uniform hydration of the dough during processing. Researchers have examined the relationship between particle size and pulse flours in noodles and Lee et al (1998) concluded that finer garbanzo bean flour resulted in darker coloured noodles while Jeffers et al (1979) found that coarser pulse flours resulted in a softer noodle. Further research is needed to determine the effects of particle size on noodles supplemented with pulse flours.

Existing research on the inclusion of pulse flours indicates that pulse flours can be successfully added to noodle formulations. More research needs to be done to look at what pulse types are suitable for this application by examining the functional and compositional properties of the flours. Blend levels also need to be examined to ensure that nutritional benefits are available to consumers while not compromising the flavour and/or texture of the end-product.

CHAPTER 3: MATERIALS AND METHODS

3.1. Flour Analysis

3.1.1. Materials

Canada western red spring (CWRS) wheat with a protein content of 13.5% (14% moisture basis) was selected for this study. The CWRS was supplied by Richardson International, and was sourced from Dundonald grain elevator in Portage La Prairie, MB. The wheat was from the 2010 crop year and was graded a No. 2 due to 0.6% fusarium damage.

Commercial whole yellow peas, whole green lentils and whole navy beans were selected for use in this study. Yellow peas were obtained from Diefenbaker Seeds in Elbow, SK. Green lentils and navy beans were donated by SaskCan (formerly Parent Seeds) located in St. Joseph, MB. All pulse samples were from the 2010 crop year. The yellow peas were graded as No. 3 due to immature seeds and cracked seed coats while the green lentils and navy beans were both graded as No. 1.

3.1.2. Wheat Milling

CWRS wheat was milled at the Canadian International Grains Institute (CIGI) in Winnipeg, MB on a Bühler pilot mill (Uzwil, Switzerland). A straight grade flour was produced according to the milling procedure described by Fu et al (2006). To make the whole wheat flour, the bran removed during the milling process was further milled using a Jacobson 120-B lab scale hammer mill (Minneapolis, MN) using a screen size of 1.19

mm. The milled bran was then before being added to the straight grade flour using a ratio of 85% wheat flour to 15% wheat bran.

3.1.3. Pulse Milling

All pulse samples were milled at CIGI using a three stage milling procedure. In the first stage, the whole seeds were coarsely ground using a Jacobson 120-B lab scale hammer mill (Minneapolis, MN) using a screen size of 3.2 mm to prepare them for subsequent milling. This material was then milled using a Bühler ML-202 lab mill (Uzwil, Switzerland) to produce pulse flours of two different particle sizes. Screen sizes for the fine flour were 10xx (132 μm) on the break side and 9xx (150 μm) on the reduction side. For the coarse flour, the screen on the break side was 10xx (132 μm) and on the reduction side was 64gg (265 μm). Roll gap widths were 0.115 and 0.5 mm on the break side and 0.6 and 0.2 mm on the reduction side. Upon completion of lab milling, any material that did not pass through the screens was pin milled twice. This was done for both the fine and coarse fractions using a Hosokawa Alpine 100 UPZ lab scale pin mill (Summit, NJ) at a speed of 22,020 ± 20 rpm and feed rate setting of 9.5. This material was then added back to the flour from the lab mill and blended for 5 minutes using a Patterson-Kelley cross flow blender (142 L, Model P-K S/N c461213, Firing Ind., Montreal, QC).

3.1.4. Flour Blending

Three flour blends (25, 30 and 35% pulse to wheat flour) were prepared for each pulse type and each particle size using a Patterson-Kelley (PK) lab blender (Model B S/n BC60314, Buflovak LLC, East Strousburg, PA). Wheat-pulse flour blends were made in

3 kg batches. All blends were made using the CWRS straight grade flour and were mixed in the PK cross flow blender for 8 minutes. All flour blends were made in duplicate.

3.1.5. Particle Size Analysis-Mastersizer

Particle size distribution for the 100% wheat and pulse flours was evaluated by laser diffraction using the Malvern Scirocco 2000 Mastersizer (Malvern Instruments Inc., Westborough, MA). The manufacturer's instructions were followed using a refractive index of 1.5. All samples were measured in duplicate. The particle size of blended flours was not analyzed.

3.1.6. Particle Size Analysis -Laboratory Sifter

The particle size for all of the 100% wheat and pulse flours was also determined using a Buhler Lab Sifter MLU-300 (Uzwil, Switzerland). A portion of each sample (200 g) was sifted (4 min) using 6 different screen sizes: 6xx (212µm), 9xx (150µm), 10xx (132µm), 12xx (112µm), 15xx (85µm), and 25xx (63µm) (Sefar America Ltd., Depew, NY). After sifting, the amount of sample remaining on each screen as well as any overs were weighed to determine the particle size distribution. Each sample was measured in duplicate. The particle size of blended flours was not analyzed.

3.1.7. Moisture Determination

Moisture contents of all flours was determined according to AACC method 44-15.02 (AACC, 1999) using a Fisher-Scientific Isotemp oven (Model #737, Fisher-Scientific, Ottawa, ON). Moisture contents were tested in duplicate and were determined periodically to ensure accurate moisture levels prior to testing.

3.1.8. Ash content

Ash content of all flours was determined according to AACC method 08-01.01 (AACC, 1999) using a Fisher-Scientific Isotemp muffle furnace (Model #550-58, Fisher-Scientific, Ottawa, ON). Samples were incinerated overnight at 600°C. All 100% wheat and pulse flours were analyzed in duplicate. For the blended flours, all replicates were measured in duplicates.

3.1.9. Protein Content

Protein content was determined using the Dumas method with a LECO FP-528 (St. Joseph, MI) according to the method of Williams et al. (1998). Conversion factors of N x 5.7 for wheat and N x 6.25 for the pulse and blended flours were used. 100% wheat and pulse flours were analyzed in duplicate, while duplicates of replicates were performed on the blended flours.

3.1.10. Total Starch Content

Total starch content of the wheat and pulse flours was determined according to AACC method 76-13.01 (AACC, 1999) using the Megazyme total starch assay kit (K-TSTA, Megazyme, Wicklow, Ireland). Analysis was performed in duplicate. Blended flours were not analyzed for total starch.

3.1.11. Total Dietary Fibre

Total dietary fibre, including soluble and insoluble fibre, were determined according to AOAC 991.43 (AOAC, 1995) with modifications that involved changes to the amount of sample analyzed. The straight grade CWRS flour sample, the whole wheat CWRS flour and all three pulse flours were analyzed at Medallion Labs (Minneapolis, MN). Moisture content was also determined at Medallion Labs using the AACC method 44-15.02 (AACC, 1999).

3.1.12. Rapid Visco Analyzer (RVA) - Pasting Profiles

Pasting profiles of all flours were evaluated using a Rapid Visco Analyzer (RVA) (Model #4 Newport Scientific Pty Ltd, Warriewood, Australia) according to AACC method 76.21.01 (AACC, 1999) using the standard Newport Scientific Method 1 (STD1). Temperature-time conditions included a heating cycle that went from 50-95°C in 282 sec, holding at 95°C for 150 sec and then cooling to 50°C. Cycles began with a 10 sec mixing at 960 rpm paddle speed, with the rest of the test having a 160 rpm paddle speed. Tests were carried out using 4.0 g of sample and 25 mL of distilled water (14% moisture basis) in an aluminium canister. 100% wheat and pulse flours were tested in duplicate while duplicates were determined on replicates of the blended flours.

3.1.13. Starch Damage

Starch damage for wheat and pulse flours was determined according to AACC method 76-31.01 (AACC, 1999) using the Megazyme starch damage assay kit (K-TSTA, Megazyme International, Wicklow, Ireland). Analysis was performed in duplicate. Blended flours were not analyzed for starch damage.

3.1.14. Water Absorption Capacity (WAC)

Water absorption capacity (WAC) was measured according to the method of Sosulski (1962) with modifications. Samples (2 g) were weighed into centrifuge tubes and distilled water (20 mL) was added. After vortexing (30 sec) and then resting (30 min), the samples were centrifuged (Centra-CL3 3750, IEC International, Needham Heights, MA) for 30 min at 1260 Relative Centrifugal Force (RCF). The volume of the supernatant was measured and results expressed as grams of water bound per gram of flour. Each 100% wheat and pulse flour was tested in duplicate while duplicates of replicates were tested for the flour blends.

3.1.15. Minolta Colour

Colour was measured using a Minolta Chroma Meter CR-310 (Konica Minolta, Japan) using a D65 illuminant. A slurry was made by mixing 20 g flour (14% moisture basis) with 25 mL distilled water for 2 min. The slurry was then allowed to rest for 5 min. Measurements were taken and colour values were recorded using the Hunter L*a*b* scale, with the L* value indicating the value of lightness(0-black, 100-white), a* indicating the degree of red-green (-a - greenness, +a- redness) and b* indicating the degree of yellow-blue (-b - blueness, +b- yellowness). Prior to testing, the Chroma Meter was calibrated against a white reference tile (L*=97.15, a*=0.44, b*=2.52). 100% wheat and pulse flour samples were measured in duplicate while duplicates of replicates were measured for the blended flours.

3.1.16. Anti-Nutritional Factors

Testing for anti-nutritional factors was done on the 100% wheat and pulse flours and noodles containing 35% pulse flour. Analysis was performed at the University of Manitoba, Food Sciences department (Winnipeg, MB). Noodles were ground using a Black and Decker household smart grind coffee grinder and were ground to pass through a #30 sieve (0.599 mm).

3.1.16.1. Total Phenolics

Total phenolic content was determined using the Folin-Ciocalteau method (Singleton & Rossi, 1965) as modified by Gao et al (2002). Samples were extracted in acetone/water (2.5 mL, 80:20, v/v) for 2 hr in a wrist action shaker (Burrell, Pittsburgh, PA,) after which they were centrifuged (10 min at 478 RCF, RC5C, Sorval, Newton, CT). A portion of the supernatant (0.2 mL) was added freshly diluted (1.5 mL, 10-fold dilution) Folin-Ciocalteu reagent (BDH, Toronto, ON). After a 5 min rest period, sodium carbonate solution (1.5 mL, 60g/L, Sigma, St. Louis, MO) was added. The mixture was then incubated for 90 min and the absorbance was measured at 725 nm using an Ultrospec 1100 pro (Biochrom, Cambridge, England). Acetone/water (80:20, v/v) was used as the blank and the standard was used was ferulic acid (Sigma, St. Louis). Samples were measured in quadruplicate and results were reported as mg/g of sample.

3.1.16.2. Phytic Acid Content

Phytic acid content was determined by the method of Latta and Eskin (1980) which is the same as the AOAC official method 986.11 with modifications. A chromatographic column (0.7 cm x 15 cm) containing 0.5 g of an anion exchange resin (100-200 mesh, chloride; AG1-X8, Bio-Rad Co., Hercules, CA) was used for the analysis. For this analysis, the digestion step was omitted. Wade reagent (I mL, 0.03% $FeCl_3 \cdot 6H_2O$ and 0.3% sulfosalicyclic acid in distilled water) was added to the extract (3 mL) and then vortexed (30 sec). The absorbance of the supernatant was measured (500 nm) with an Ultrospec 1100 pro (Biochrom, Cambridge, England) using water as the blank. All samples were tested in duplicate.

3.1.16.3. Trypsin Inhibitors

Trypsin inhibitor activity was measured using AACC method 22-40.01 (AACC, 1999) with modifications to the sample extraction procedure. Sample extraction was done using 1g of sample for the straight grade CWRS flour, the CWRS whole wheat flour and all noodle samples while the pulse flours were extracted using 0.5 g. All samples were extracted with 25 mL of 0.01 N NaOH for 3 hrs. Extracts were diluted in distilled water to different percentages depending on the pulse type so that 1.0 mL could inhibit 50% of trypsin activity. Results were reported as TIU/mg. All samples were tested in duplicate.

3.1.17. Statistical Analysis

All data were recorded as means ± SD and was analyzed using JMP 8.0 (SAS, North Carolina). For the 100% pulse flour analysis, two way analyses of variance (ANOVA) were performed on all data, except for particle size, dietary fibre content and water absorption capacity. For the blended pulse flours, two way analysis of variance (ANOVA) was performed on all data except for total dietary fibre. Multiple comparisons of the means were performed using Tukey's test ($p \leq 0.05$). The 100% CWRS straight grade and 100% whole wheat flours were not included in the ANOVA analysis as they were only milled to one particle size. They were therefore used only for comparison.

3.2. Dried Asian White Salted Noodles

3.2.1. Noodle Processing

Noodles were processed at CIGI in the pilot Asian noodle lab and were processed in random order, however, processing of each replicate for each pulse type was completed before beginning the next rep of the next pulse type. Flour samples were mixed for 10 min with distilled water and 2% salt (NaCl) in an Ohtake noodle machine horizontal vacuum mixer (Tokyo, Japan) with the vacuum turned off. The amount of distilled water required changed depending on the amount of pulse flour in the blend. Dough formulations for each flour blend are provided in Table 5. Prior to its addition, the salt was dissolved in the distilled water.

Table 5: Pulse Noodle Dough Formulations

Pulse Flour (%)	Wheat Flour (%)	Salt (NaCl) (%)	Distilled Water (%)
0	100	2	32
25	75	2	27
30	70	2	26
35	65	2	25

The salt and water mixture was added to the flour within the first 15 s of mixing. The horizontal mixer was set at a speed of 120 rpm and was occasionally stopped (2-3 times, no longer than 5 s at a time) to scrape the sample from the lid and edges of the mixing bowl.

After mixing (10 min), the noodle crumb was removed from the mixer and evaluated both visually and by touch. This evaluation was done to ensure the noodle crumb contained sufficient moisture for sheeting. If the noodle crumb was too wet or too dry, the amount of water would be adjusted prior to sheeting. The crumb was covered and allowed to rest (10 min) before being placed into the Ohtake pilot noodle machine (Tokyo, Japan). In order to form the dough sheet, the first pass of the dough crumbs through the rolls on the noodle machine was at a speed of 1.3 rpm and between a gap width of 5.08 mm. The resulting dough sheet was then folded and immediately passed through the noodle machine a second time at a gap width of 5.10 mm but at an increased speed of 2.4 rpm. The dough sheet was then covered with plastic and allowed to rest (10 min).

After resting, the thickness of the dough sheet was further reduced using progressively smaller gap widths and increased speeds. The third pass had a gap width of 3.0 mm and a speed of 3.8 rpm, the fourth pass had a gap width of 1.8 mm and of 5.2 rpm and the fifth and final pass had a gap width of 1.3 mm and a speed of 5.2 rpm. Before the dough sheet was cut, the appearance was evaluated and scored on a scale of 1 to 10 where 1 indicated dough that was dry and lacked hydration with little dough development and a score of 10 was an indication of excellent dough development with optimal hydration (Appendix A).

After sheeting, the noodles were cut using a #18 cutter (1.7mm) (Ohtake, Tokyo, Japan) and then hung on drying rods, which were immediately put into the Ohtake noodle machine dryer (Tokyo, Japan). The drying cycle consisted of 9 segments, each with a different temperature setting, relative humidity (%) and time (min) (Table 6).

Table 6: Drying Cycle Used for Dried Asian White Salted Noodles.

Segment	Temperature (°C)	Relative Humidity (%)	Time (min)
1	25	90	30
2	30	90	30
3	30	85	30
4	35	85	60
5	35	80	45
6	30	75	45
7	30	70	45
8	25	65	45
9	25	60	90

(E. Assefaw, personal communication, January, 2011)

After the noodles were dried, they were manually cut into approximately 23 cm strands, and kept in sealed plastic bags. The plastic bags were then stored in opaque plastic bins and kept at room temperature until analysis. Noodles made from 100% straight grade wheat and 100% whole wheat were made in triplicate, while all noodles made from pulse/wheat flour blends were made in duplicate.

3.2.2. Optimum Cooking Time (OCT)

In order to determine the optimum cooking time (OCT), noodles (5 g) were added to distilled boiling water (300 mL), which was kept at a rolling boil. Starting at the 4 minute mark, a noodle was removed every 30 s and was pressed between two Plexiglass sheets. OCT was determined when there was no visible core in the noodle strand. Samples were tested in duplicate.

3.2.3. Texture Analysis

Instrumental texture was evaluated using the TA-XT2 Texture Analyzer (Stable Micro System, Surrey, UK) in compression mode. Noodles were cut in half and cooked according to their OCT. Noodles were then drained in a sieve, tapped 5 times, and placed in distilled water (22°C) for 90 s to halt the cooking process. Noodles were removed from the water and centred on a translucent Plexiglass base plate. A cutting blade (TA 47) was raised 4.5 mm above the base plate and used to cut the noodles to a fixed compression depth of 4.4 mm (0.1 mm from the baseplate). The speed of the crosshead was set to 0.2 mm/s. The noodles were tested 3.5 min after they were removed from the distilled water (22°C). All samples were measured in duplicate.

3.2.4. Dried Noodle Colour

Dried noodle colour was measured using a Minolta Chroma Meter (CR-310, Konica Minolta, Japan) using a D65 illuminant. Noodle strands (20) were cut into 7.5mm strands and attached to a white piece of illustration board. Measurements were taken and colour values were recorded using the Hunter L*a*b* scale. The Chroma Meter was calibrated against a white reference tile (L*=97.15, a*=0.44, b*=2.52) prior to sample evaluation. Samples were measured in duplicate.

3.2.5. Cooked Noodle Colour

Cooked noodle colour was measured using a Minolta Chroma Meter (CR-310 Konica Minolta, Japan) using a D65 illuminant. Noodle strands (8) were cut in half and then added to boiling distilled water (600 mL) and allowed to cook for their predetermined OCT. Noodles were then drained, and immersed in distilled water (22ºC for 90 s) to halt the cooking process. Noodles were removed from the water and put on a translucent Plexiglass plate. Colour measurements were taken 3.5 minutes after the noodles were removed from the distilled water (22ºC). Colour values were recorded using the Hunter L*a*b* scale using the same parameters as described in the dried noodle colour analysis. Samples were measured in duplicate.

3.2.6. Statistical Analysis

Noodle quality data was recorded as means ± SD and was analyzed using JMP 8.0 (SAS, North Carolina). Two way analysis of variance (ANOVA) was performed on all data, except for OCT. Multiple comparisons of the means were performed using Tukey's test

($p \leq 0.05$). Noodles made with the 100% CWRS straight grade flour and 100% CWRS whole wheat flour were not included in the ANOVA analysis as they were made with flour of only one particle size and were therefore only used for comparison.

3.3. Sensory Evaluation

3.3.1. Panelist Selection

All sensory sessions were conducted at CIGI. Panelists were invited via e-mail to participate (Appendix B). A total of nine panelists agreed to take part in the sensory sessions. All panelists were required to read and sign a letter of consent (Appendix C).

3.3.2. Training Sessions

A total of four, 1 hour, training sessions were held once a day over consecutive days. All sessions, training and test, were held in the Analytical Services lab at CIGI. This location was chosen for its proximity to the cooking facilities and ease of access for panelists. The focus of the first training session was to discuss sensory panel procedures and to introduce the panelists to the textural and flavour properties they would be evaluating during the panel sessions. A diagram of the mouth and teeth was provided to all panelists in order to illustrate how to properly bite and/or chew the noodles. Panelists were asked to evaluate the noodles for 6 parameters (smoothness, elasticity, firmness, cohesiveness, flavour intensity and aftertaste) using 14 cm semi-structured line scales (Appendix D). Definitions were provided for each parameter and the reference sample (noodles made with 100% straight grade CWRS flour) was placed on each of the line scales to assist the panellists with their evaluations. Placement of the reference sample on each line scales was based on expert opinion and was as follows: smoothness at 1.3 cm, elasticity at 11.5 cm, firmness at 10.2 cm, cohesiveness at 3.2 cm, flavour intensity at 1.3 cm and aftertaste at 1.3 cm.

In the first training session, panelists were given the reference sample and one sample of pulse noodles for evaluation. All samples were cooked according to their predetermined optimum cooking time, drained, tapped 5 times, and then placed into tap water (22°C). The noodles were then portioned into bowls, also containing tap water (22°C) and immediately served to the panelists. Panelists were instructed to take one noodle at a time into the mouth for evaluation. After all panelists had completed their individual evaluations, discussion with the group followed. During this discussion, panelists were encouraged to provide suggestions and comments, to discuss any misunderstandings or problems with the parameters they were measuring, and to ensure that they were following the proper evaluation procedures.

In the subsequent training sessions, panelists were gradually introduced to the evaluation of three pulse noodle samples plus the reference sample. During the course of training, each type of pulse noodle was evaluated at least once. Only one pulse type was evaluated per training or test session in order to minimize panellist fatigue and difficulty. The evaluation of the noodles was time sensitive, which prevented panelists from re-evaluating the reference sample after its initial evaluation during both the training and test sessions. Therefore, the training sessions focused on the panelists becoming comfortable with the ballots, the testing parameters and procedures as well as the reference sample.

3.3.3. Test Sessions

A total of twelve test sessions were held to evaluate all of the samples (3 pulse types x 3 blend levels x 2 particle sizes x 2 replications). Test sessions (30 min) were held twice a day, once in the morning and once in the afternoon and took a total of two weeks to complete.

At each test session, panelists received the reference sample (R) plus three samples coded with three digit random numbers. Samples were randomized by blend level and particle size however one pulse type was completed before beginning analysis on a different pulse type. Panelists were supplied with distilled water and raw carrots to cleanse their palate between samples.

During the last two test sessions, panelists were asked to evaluate one additional sample. To accommodate this, the test regular session was followed with an additional test which involved providing the panellist with a new ballot along with the reference sample and a three digit coded sample which was noodles made from 100% whole wheat flour.

3.3.4. Statistical Analysis

All sensory data was recorded as means ± SD and was analyzed using JMP 8.0 (SAS, North Carolina). The REML (Restricted or Residual Maximum Likelihood) method was used to evaluate all of the sensory results as the panelists were considered to be random effects. The main effects of pulse type, blend level, particle size and subsequent interactions were treated as fixed effects, whereas panelists and any interactions involving panelists were treated as random effects. For the random effects, variance components are included in Appendix E. These are included since these random effects are not of interest in this study, but are sources of variation that must be accounted for. Multiple comparisons of the means were performed using Tukey's test ($p \leq 0.05$).

CHAPTER 4: RESULTS AND DISCUSSION

4.1. 100% Wheat and Pulse Flours

4.1.1. Characteristics and Composition

4.1.1.1 Particle Size

The particle size of flour has been shown to have an effect on functional properties such as WAC, and certain starch characteristics (Kerr et al, 2000). Therefore it is reasonable to expect that flour particle size may have an effect on noodle processing parameters and end product quality. In Canada, Food and Drug regulations stipulate that wheat flours need to have a particle size less than 149 µm whereas pulse flours are considered a non-standardized product and therefore are not regulated to have a size (Department of Justice, 2011).

Table 7 summarizes the particle size distribution of the wheat and pulse flours as determined by the Mastersizer. Fine and coarse pulse flours were produced using different screen sizes. For the fine pulse flours, a screen with openings of 150 µm was used and produced flours that had a 90% particle distribution between 161.01 and 162.76 µm or smaller. The coarse flours, which were milled using a screen size of 265 µm produced a 90% particle distribution between 248.57 and 257.65 µm or smaller. Differences between the fine and coarse pulse flours were also observed at the 50 and 10% distribution levels that confirm a difference in particle size distribution between the coarse and fine flours (Table 7). All of the pulse flours had a finer particle size at the 10% marker compared to the CWRS straight grade flour. These differences could be a result of the pin milling that was done on the material that did not pass through the screens during the roller milling. This material is referred to as the overs and was pin milled before being incorporated back into the pulse flour. At the 50 and 90% marks, the pulse flours were larger in size than the CWRS straight grade flour. The CWRS whole wheat flour had both the broadest particle size distribution and largest particles. The bran that was incorporated back into the flour to product whole wheat flour was hammer milled using a screen size of 1.19 mm, which would account for the large particles of bran in the flour making it the coarsest of all of the flours milled.

Table 7: Mastersizer Particle Size Distribution of Wheat and Pulse Flours[1]

Flour	Distribution (μm)[2]		
	10 %	50 %	90 %
CWRS Straight Grade	21.124	68.635	135.719
CWRS Whole Wheat	31.455	122.741	1170.171
100% Fine Yellow Pea	16.218	71.156	162.764
100% Coarse Yellow Pea	20.270	107.854	253.273
100% Fine Green Lentil	16.959	80.418	161.009
100% Coarse Green Lentil	20.887	106.875	257.646
100% Fine Navy Bean	13.186	54.464	161.983
100% Coarse Navy Bean	17.358	104.715	248.569

1 Results are the mean of duplicate measurements.
2 Distribution (μm) represents the size of particles at each percentage of volume

Particle size distributions were also measured using a laboratory sifter (Figure 1). These results indicated the CWRS straight grade flour had the highest percentage of fine particles of all milled flours with the greatest percentage of particle accumulation at approximately 63 μm. Figure 1 also illustrates that fine pulse flours tended to collect

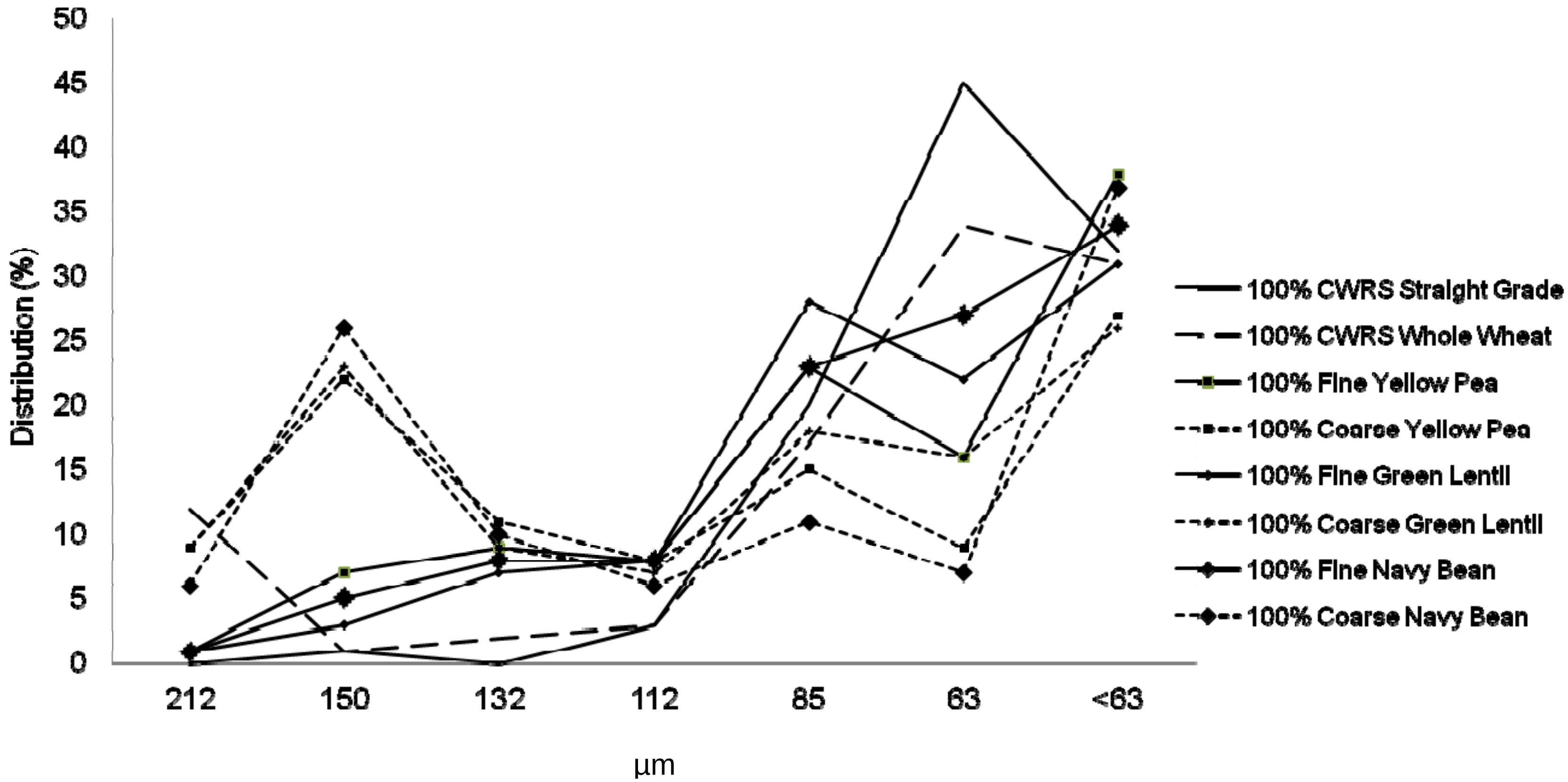

Figure 1. Mean Particle Size Distribution of Wheat and Pulse Flours using a Laboratory Sifter

around 85 to < 63 μm whereas the coarse flours had a large number of particles around 150 μm.

Flours were milled to these particle sizes to determine if particle size of flour has an effect on some of the compositional and functional properties of pulse flours when incorporated into dried Asian white salted noodles. Results from both the mastersizer and the laboratory sifter indicated differences in particle size between the pulse flours milled using different screen sizes which resulted in fine and coarse flours. Both methods of analysis also indicated that the CWRS straight grade flour had the greatest percentage of fine particles. The CWRS whole wheat flour had the greatest percentage of coarse particles at 212 μm which is due to the incorporation of bran. As previously mentioned, the only size reduction performed on the bran was hammer milling. The amount of bran (15%) that was added back in to make a whole wheat flour explains why the large particles only account for approximately 12% of the whole wheat flour.

4.1.1.2. Ash

Proximate composition of the wheat and pulse flours can be seen in Table 8. Ash contents of the yellow pea, green lentil and navy bean flours were all greater than the values for the CWRS straight grade flour. Higher ash values are an indication of higher mineral contents in the pulse flour. Of the three pulses, beans have the highest mineral content (Oomah et al, 2011), which would account for the navy bean flour having the highest ash value (4.35%)

Similarly to the pulses, the CWRS whole wheat flour had a higher ash content than the CWRS straight grade flour. In wheat, the bran contains higher levels of minerals than the endosperm (USDA, 2011) and could account for the ash content of whole wheat flour being higher than in the straight grade flour.

4.1.1.3. Protein

Protein contents of the pulse flours were also higher than those of the wheat flours (Table 8). Significant differences ($p \leq 0.05$) were observed among all the pulse flours which had protein contents between 22.68 and 26.99% whereas CWRS straight grade and CWRS whole wheat contained only 15.73 and 15.84% protein, respectively. Protein contents of pulses can vary depending on plant variety, maturity and environmental conditions (Roy et al, 2010), however, protein contents of pulses are about twice that found in cereal grains (Rochfort & Panozzo, 2007).

Table 8: Proximate Composition of Wheat and Pulse Flours (db)[1]

	100% CWRS Straight Grade[2]	100% CWRS Whole Wheat[3]	100 % Yellow Pea		100% Green Lentil		100% Navy Bean	
			Fine	Coarse	Fine	Coarse	Fine	Coarse
Ash (%)[4]	0.61 ± 0.01	1.81 ± 0.02	2.44 ± 0.02[d]	2.48 ± 0.04[d]	2.71 ± 0.00[c]	2.72 ± 0.00[c]	4.14 ± 0.03[b]	4.56 ± 0.01[a]
Protein (%)[4]	15.73 ± 0.01	15.84 ± 0.04	22.68 ± 0.02[d]	22.73 ± 0.00[d]	26.80 ± 0.09[b]	26.99 ± 0.01[a]	25.72 ± 0.02[c]	25.87 ± 0.04[c]
Starch (%)[4]	75.32 ± 1.05	63.26 ± 0.05	49.78 ± 0.04[a]	48.69 ± 0.04[a]	44.99 ± 0.59[b]	44.81 ± 0.74[b]	36.83 ± 0.45[c]	38.06 ± 0.67[c]

1 Results are the means of 2 measurements ± SD.
23 CWRS straight grade and whole wheat flours were not included in the statistical analysis as they were available at only one particle size and are included for comparison purposes.
4 Means followed by the same letter are not statistically different ($p \leq 0.05$).

4.1.1.4. Total Starch

In contrast to protein and ash, the total starch content was lower in pulse flours compared to both CWRS straight grade and whole wheat flours (Table 8). Significant differences ($p \leq 0.05$) were also observed between pulse type with yellow pea having the most starch followed by green lentil and navy bean. Both starch type and content can affect the functional properties of the flours, which in turn can affect their suitability in end-product applications.

Both Martin et al (2004) and Baik & Lee (2003) found that amylose content of flour was related to noodle textural characteristics while Crosbie (1991) concluded that pasting properties of the starch were important in noodle quality. Amylose contents of selected pulses have been reported to be 25% of total starch (Table 2) whereas in wheat, amylose content is approximately 21-30% of the total starch (Demeke et al, 1997) Wheat flours have a higher total starch content than pulse flours and therefore tend to have a higher amylose content. The lower amylose content of the pulse flours could have an effect on the end noodles textural quality.

4.1.1.5. Total Dietary Fibre

Similarly to protein and ash, pulse flours generally contained higher amounts of total dietary fibre as well as soluble and insoluble fibre compared to the wheat flours (Table 9). The high levels of total dietary fibre in the pulse flours can be attributed to the use of both the cotyledon and hull for flour production. The hulls of pulses are

Table 9: Total Dietary Fibre Content of Wheat and Pulse Flours (db)

	100% CWRS Straight Grade Flour	100% CWRS Whole Wheat Flour	100% Yellow Pea Flour	100% Green Lentil Flour	100% Navy Bean Flour
Total Dietary Fibre (%)	2	11	12.4	19.5	14.7
Insoluble (%)	1.3	9.7	11.1	14.6	13.1
Soluble (%)	0.7	1.4	1.3	4.9	1.7

rich in total dietary fibre and are a major source of insoluble fibre (Tosh & Yada, 2010). Navy beans also benefit by having higher soluble fibre (Table 9). It was assumed that the total dietary fibre content is not affected by particle size, and therefore, only the fine pulse flours were analyzed.

When comparing the proximate composition of pulse flours to wheat flours, it is apparent that pulse flours offer a nutritional advantage. They are higher in protein, vitamins and minerals and total dietary fibre**.** Sabanis et al (2006), Cabello et al (1992) and Zhao et al (2005) all saw an increase in nutritional status when certain pulse flours were added to various food product formulations. The incorporation of pulse flours into dried white salted noodles undoubtedly would boost the nutritional profile of the noodles and make them a healthier food product for consumers. In addition, the changes in composition will also have an effect on the functional attributes of the pulse flours in comparison to wheat flours.

4.1.2. Functional Properties

4.1.2.1. Pasting Properties

The Rapid Visco Analyzer (RVA) was used to determine pasting characteristics of both the wheat and pulse flours. It measures the pasting properties under a controlled increased in temperature while being exposed to constant shearing conditions (Singh, 2011). High peak viscosity, high breakdown and low setback have all been correlated with good noodle quality (Bhattacharya & Corke, 1996). The summaries of ANOVA for peak viscosity, breakdown and setback can be seen in Tables 10-12. The mean values for peak viscosity, breakdown and setback are presented in Table 13 for yellow pea, green lentil and navy bean flours as well as for both wheat flours.

Table 10: Summary of Analysis of Variance Results for Peak Viscosity of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	6914.6667	10372.00	<0.0001
Particle Size (PS)	1	3.0000	9.0000	0.0240
PT * PS	2	38.0000	57.0000	0.0001

Table 11: Summary of Analysis of Variance Results for Breakdown of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	210.16667	97.0000	<0.0001
Particle Size (PS)	1	14.08333	13.0000	0.0113
PT * PS	2	6.16667	2.8462	0.1351

Table 12: Summary of Analysis of Variance Results for Setback of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	8324.6667	292.0936	<0.0001
Particle Size (PS)	1	6.7500	0.4737	0.5170
PT * PS	2	38.0000	1.3333	0.3318

Table 13: RVA Mean Results[1] of Wheat and Pulse Flours[2]

	100% CWRS Straight Grade[3]	100% CWRS Whole Wheat[4]	100% Yellow Pea		100% Green Lentil		100% Navy Bean	
			Fine	Coarse	Fine	Coarse	Fine	Coarse
Peak Viscosity (RVU)[5]	187.0 ± 1.41	138.0 ± 4.24	176.0 ± 0.00[a]	173.0 ± 0.00[b]	156.5 ± 0.71[c]	160.5 ± 0.71[d]	119.5 ± 0.71[e]	115.5 ± 0.71[f]
Breakdown (RVU)[5]	71.0 ± 0.00	53.0 ± 1.41	15.5 ± 0.71[a]	11.5 ± 0.71[ab]	9.5 ± 0.71[b]	7.5 ± 2.12[bc]	3.5 ± 0.71[cd]	3.0 ± 0.00[d]
Setback (RVU)[5]	89.0 ± 0.00	77.5 ± 2.12	117.0 ± 0.00[a]	123.5 ± 2.12[a]	87.5 ± 0.71[b]	86.0 ± 8.49[b]	56.0 ± 2.83[c]	55.5 ± 0.71[c]

1 All results expressed as RapidVisco Units (RVU).
2 Results are the means of 2 measurements ± SD.
34 CWRS straight grade and whole wheat flours were not included in the statistical analysis as they were available at only one particle size and are included for comparison purposes.
5 Means followed by the same letter are not statistically different ($p \leq 0.05$)

Peak viscosity refers to the point at which a rapid increase in viscosity occurs because enough starch granules have swelled (Kaur et al, 2007). A significant interaction was observed between pulse type and particle size. Significant differences ($p \geq 0.05$) were observed between particle size and pulse type for peak viscosity. Coarse flours for both yellow pea and navy bean flours had higher peak viscosities than their fine counterparts, whereas the green lentil fine flour had a higher peak viscosity than the coarse (Table 13).

All of the pulse flours had a lower peak viscosity than the CWRS straight grade control flour. High peak viscosities of flours have been associated with a softer noodle texture (Crosbie & Ross, 2010). The lower peak viscosity values of the pulse flours could be a predictor of noodles with a firmer texture. The CWRS whole wheat control also had a peak viscosity lower than the CWRS straight grade control and was in the range observed for the pulse flours.

Breakdown values were much lower for all of the pulse flours compared to both the CWRS straight grade and whole wheat flours. Breakdown is the difference between peak and hot paste viscosities, which is the difference of the maximum and minimum viscosities (CIGI, 2010). Oda et al (1980) concluded that noodles made with wheat with higher breakdown values were related to good noodle eating quality. Among the pulse flours, significant differences ($p \geq 0.05$) were observed for the main effects of pulse type and particle size however no significant interaction effect was observed. For all pulse types, the fine flours had higher breakdown values compared to the coarse flours. The breakdown was generally higher for the yellow pea, followed by green lentil and navy bean.

Particle size did not have an effect on the setback of the pulse flours as no significant differences ($p \geq 0.05$) were observed between the coarse and fine flours (Table 12). Yellow pea flour had the highest setback values followed by the CWRS straight grade flour, green lentil flours, CWRS whole wheat and lastly, the navy bean flours. Setback is the measurement of syneresis, or the release of water, from the starch while cooling (Kaur et al, 2007). Setback values can be used as an indicator of starch retrogradation (Wang et al, 2010), which can have an effect on the cooked noodle quality resulting in a noodle that is too soft and sticky (Riva et al, 2000). Higher setback values, which were observed in the pulse flours, are an indication that the noodles made with these flours may be more susceptible to retrogradation.

4.1.2.2. Starch Damage

Starch damage is a consequence of milling and has been found to be associated with seed hardness (Lindhal & Eliasson, 1992). Similarly to particle size, it is understood that starch damage has an effect on determining optimum water absorption when formulating noodle dough (Hatcher et al, 2002). Research has indicated that wheat flours with higher starch damage require more water in noodle dough formulation than wheat flours with lower starch damage (Hatcher et al, 2002). Significant main effects of pulse type and particle size were found for starch damage, however no interaction effects were observed (Table 14). Lower starch damage values were found for all of the pulse flours compared to the CWRS straight grade and whole wheat flours with the lowest values obtained for navy bean flour (Table 15). Lower starch damage values in wheat used in dough formulations have been associated with lower water absorptions which were consistent with the noodle dough formulations used in this study (Table 5).

Table 14: Summary of Analysis of Variance Results for Starch Damage of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	6.86	147.48	<0.0001
Particle Size (PS)	1	0.33	14.05	0.0095
PT * PS	2	0.13	2.82	0.1372

Table 15: Starch Damage Values of Wheat and Pulse Flours (db)[1]

	Starch Damage (%)	
100 % CWRS Straight Grade[2]	10.54 ± 0.071	
100% CWRS Whole Wheat[3]	8.35 ± 0.092	
	Fine	Coarse
100% Yellow Pea[4]	2.36 ± 0.099[ab]	2.11 ± 0.049[b]
100% Green Lentil[4]	2.84 ± 0.339[a]	2.23 ± 0.106[b]
100% Navy Bean[4]	0.86 ± 0.000[c]	0.74 ± 0.028[c]

1 Results are the means of 2 measurements ± SD.
23 CWRS straight grade and whole wheat flours were not included in the statistical analysis as they were available at only one particle size and are included for comparison purposes.
4 Means followed by the same letter are not statistically different ($p \leq 0.05$)

The composition and total starch content of the pulse flours could contribute to the differences as all three pulse flours contained significantly different amounts of starch

(Table 8), and were all lower in total starch content than both the CWRS straight grade and whole wheat flours. Starch damage values were lowest in the navy bean flours which contained the lowest amount of total starch. Starch damage was lower for the coarse pulse flours, primarily due to the difference seen for the green lentil flour. Lindahl & Eliasson (1992) and Oh et al (1985) both reported that starch damage increased with finer flour fractions indicating increased milling caused more starch damage.

The CWRS straight grade flour had the highest starch damage values of all the flours. This is due to the milling method which was done using a pilot roller mill. The increased number of reduction rolls on a pilot mill, compared to the lab mill, makes the flour more susceptible to starch damage.

4.1.2.3. Water Absorption Capacity (WAC)

Understanding WAC is critical when developing product formulations that require the development of doughs. Currently, operator experience and handfeel are two of the more common methods in determining good dough consistency in noodle making (Hatcher et al, 2002) and were the methods used in this study to determine optimal hydration. WAC results for both the wheat and pulse flours can be seen in Table 16. Values remained the same at 1.66 g/g for fine flours regardless of pulse type and were lower at 1.11 to 1.12 g/g for the coarse flours. From these results, it would appear that with a greater surface area the smaller particles were able to take in more water. Hatcher et al (2002) examined the effect of particle size on water absorption and concluded that faster water uptake by finer particles would make fine flours more suitable for noodle making. Kaur & Singh (2005) reported WAC values for chickpea flours to be between 1.34 to 1.47 g/g while Kaur et al (2007) reported values between 1.25 to 1.38 g/g for certain varieties of field peas. These values are between those for the coarse and fine flours used in this study and, while no particle sizes were reported in these papers, these results support the conclusion that pulse flours have higher WAC.

Table 16: Water Absorption Capacity of Wheat and Pulse Flours (db)[1].

	Water Absorption Capacity (g/g)	
100 % CWRS Straight Grade[2]	0.84	
100% CWRS Whole Wheat[3]	0.86	
	Fine	Coarse
100 % Yellow Pea[4]	1.66[a]	1.12[b]
100 % Green Lentil[4]	1.66[a]	1.11[b]
100 % Navy Bean[4]	1.66[a]	1.12[b]

1 Results are the means of 2 measurements.
23 CWRS straight grade and whole wheat flours were not included in the statistical analysis as they were available at only one particle size and are included for comparison purposes.
4 Means followed by the same letter are not statistically different ($p \leq 0.05$)

CWRS straight grade and whole wheat had WAC of 0.84 and 0.86 g/g respectively, both considerably lower than that for the pulse flours. The higher fibre content in the pulse flours (Table 9) may have contributed to the higher water absorption. Pectin is one of the components in the pulse hulls and is believed to increase water absorption because of its hydrophilicity (Tosh & Yada, 2010).

4.1.2.4. Colour

Evaluating the colour of flours used for making noodles is important as it will undoubtedly affect the colour of the final product and will ultimately have an impact on consumer acceptability. Colours were evaluated for all flours and the L*, a* and b* results were analyzed using ANOVA are summarized in Tables 17-19. The mean values of L*, a*, b* are provided in Table 20.

For L*, a measurement of lightness, pulse type was the only variable that had a significant effect on the lightness of the flours (Table 17). Green lentil flour had significantly lower L* values than both yellow pea and navy bean flours. All pulse flours had lower L* values compared to the CWRS straight grade flour, which had an L* value of 85.26. The CWRS whole wheat sample also had a lower L* values than the CWRS straight grade, however, the yellow pea and navy bean flours were lighter than the whole wheat control.

Table 17: Summary of Analysis of Variance Results for L* Values of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	105.21447	70.5987	<0.0001
Particle Size (PS)	1	1.89607	2.5445	0.1618
PT * PS	2	1.60020	1.0737	0.3994

Table 18: Summary of Analysis of Variance Results for a* Values of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	63.156350	111452.4	<0.0001
Particle Size (PS)	1	0.000300	1.0588	0.3432
PT * PS	2	0.009950	17.5588	0.0031

Table 19: Summary of Analysis of Variance Results for b* Values of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	784.76412	4708585	<0.0001
Particle Size (PS)	1	1.0518e-30	0	1.000
PT * PS	2	0.16515	990.9000	<0.0001

Table 20: Summary of L*, a* and b* Values for Wheat[1] and Pulse Flours[2].

Flour	L*[3]	a*[3]	b*[3]
100% Fine Yellow Pea	73.53 ± 0.028[a]	0.47 ± 0.007[b]	32.73 ±0.000[a]
100% Coarse Yellow Pea	75.14 ± 2.114[a]	0.39 ± 0.000[c]	32.40 ± 0.000[b]
100% Fine Green Lentil	67.40 ± 0.007[b]	-3.64 ± 0.282[d]	29.40 ± 0.014[c]
100% Coarse Green Lentil	68.34 ± 0.000[b]	-3.66 ± 0.028[d]	29.54 ± 0.007[d]
100% Fine Navy Bean	74.03 ± 0.000[a]	1.71 ± 0.007[a]	13.98 ± 0.007[e]
100% Coarse Navy Bean	73.87 ± 0.007[a]	1.77 ± 0.000[a]	14.17 ± 0.014[f]

1 Values for 100% straight grade and 100% whole wheat were L*:85.26, a*: -0.48, b*: 14.77 & L*: 72.9,a*: 3.97, b*: 14.42 respectively for duplicate measurements.

2 Results are the mean of 2 measurements± SD.

3 Means with the same letter in the same column are not significantly different ($p \geq 0.05$).

For a* values, there was a significant interaction between pulse type and particle size. Significant differences for a* values were found between the coarse and fine yellow pea flours and among the three pulse flour types. Using a flour slurry to measure colour usually eliminates the influence of particle size on colour values (Oliver et al, 1993). However the differences observed due to particle size for the a* values of coarse and fine yellow pea flour could reflect their lack of ability to fully dissolve as well as the overall intensity of the seed colours. Previous results indicated that finer flours had a higher water absorption capacity (Table 16) which could be linked to the reduced solubility. The a* value of the yellow pea flours were similar to the CWRS straight grade flour. Not surprisingly, the green lentil flours had the lowest a* value, an indication of greenness, while the navy bean flours had the highest a* values.

There was a significant interaction between pulse type and particle size for b* values. The green lentil flours had the most obvious differences in comparison to the CWRS straight grade flour, which was also seen for the L* and a* values. All of the pulse flours were significantly different ($p \geq 0.05$) from each another and for each flour type, there was a significant difference between the coarse and fine flours. The b* values for the coarse yellow pea flour were lower than those for the fine flour, while the opposite was true for the green lentil and navy bean flours. It should be noted that all differences were less than 0.5 units and were minor in comparison to the effect of flour type.

Differences in colours between pulse types can be attributed to the presence of different and varying amounts of phenolic compounds which contribute to the pigmentation of the seeds (Naczk & Shahidi, 2004). It is been proven that the colours of the pulse flours differ from the two wheat flours and from each other. This will have an impact on the colour of end products produced from these flours and could affect consumer acceptability.

4.1.3. Anti-Nutritional Factors

All of the flours used in this study were analyzed for three anti-nutritional factors. Total phenolics, trypsin inhibitors and phytic acid were all evaluated and analyzed for both fine and coarse flours. Summaries of ANOVA for the anti-nutritional factors are provided in Tables 21-23.

Table 21: Summary of Analysis of Variance Results for Total Phenolics of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	470.95628	293.0483	<0.0001
Particle Size (PS)	1	1.51545	1.8859	0.1865
PT * PS	2	3.63826	2.2639	0.1327

Table 22: Summary of Analysis of Variance Results for Trypsin Inhibitors of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	399.40848	2165.160	<0.0001
Particle Size (PS)	1	0.71639	7.7669	0.0317
PT * PS	2	1.40322	7.6067	0.0226

Table 23: Summary of Analysis of Variance Results for Phytic Acid of Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	185.45505	23.5084	<0.0014
Particle Size (PS)	1	14.19296	3.5982	0.1066
PT * PS	2	6.80502	0.8626	0.4685

Pulse type was the only main effect that had an effect on total phenolics of the pulse flours. The mean values can be seen in Table 24a. The green lentil flour had a significantly higher phenolic content compared to the other two pulse flours. Phenolics are known to contribute to plant pigmentation (Naczk & Shahidi, 2004), which could explain why the navy bean and yellow pea flours had lower phenolic contents compared to the darker green lentil flours.

Table 24a: Mean Values of Total Phenolics (mg/g) of Wheat and Pulse Flours(db)[1]

100% CWRS Straight Grade[2]	0.59 ± 0.06
100% CWRS Whole Wheat[2]	1.07 ± 0.08
100% Yellow Pea	1.01 ± 0.07[b]
100% Green Lentil	10.32 ± 1.67[a]
100% Navy Bean	0.82 ± 1.67[b]

[1] Means of all measurements ± SD of fine and coarse particle size. Means followed by the same letter are not statistically different ($p \leq 0.05$)

[2] CWRS straight grade and whole wheat flours were not included in the statistical analysis as they were available at only one particle size and are included for comparison purposes.

Trypsin inhibitors were the only anti-nutritional factor that had a significant interaction between pulse type and particle size. The mean values can be seen in Table 24b. The navy bean flours had the highest levels of trypsin inhibitors and were significantly higher (($p \geq 0.05$) than both the green lentil and yellow pea flours. Both the fine and coarse green lentil flour had significantly higher trypsin inhibitor levels than fine yellow pea flour and the coarse green lentil flour had higher levels than the coarse yellow pea flour.

Table 24b: Mean[1] Values of Trypsin Inhibitors (TIU/mg) of Wheat and Pulse Flours (db)

100% CWRS Straight Grade[2]	0.99 ± 0.04	
100% CWRS Whole Wheat[2]	0.83 ± 0.04	
	Fine	Coarse
100% Yellow Pea	3.75 ± 0.23[d]	4.88 ± 0.38[cd]
100% Green Lentil	5.74 ± 0.08[bc]	6.53 ± 0.16[b]
100% Navy Bean	17.59 ± 0.40[a]	17.13 ± 0.41[a]

1 Mean of all measurements ± SD. Means followed by the same letter are not statistically different ($p \leq 0.05$)

2 CWRS straight grade and whole wheat flours were not included in the statistical analysis as they were available at only one particle size and are included for comparison purposes.

Phytic acid content of the wheat and pulse flours can be seen in Table 24c. Only pulse type had a significant main effect on phytic acid content. The navy bean flour had a significantly higher phytic acid content than the other two pulse flours which was similar to the findings for trypsin inhibitors.. This is in agreement with other research that has shown that beans have higher levels of both these anti-nutritional factors than lentils and peas (Champ, 2002).

Table 24c: Mean Values of Phytic Acid Content (mg/g) of Wheat and Pulse Flours (db)[1]

100 % CWRS Straight Grade[2]	2.67 ± 0.10
100 % CWRS Whole Wheat[2]	15.50 ± 3.12
100 % Yellow Pea	7.62 ± 0.97[b]
100 % Green Lentil	9.62 ± 0.75[b]
100 % Navy Bean	16.78 ± 3.66[a]

1 Means of all measurements ± SD of fine and coarse particle size. Means followed by the same letter are not statistically different ($p \leq 0.05$)

2 CWRS straight grade and whole wheat flours were not included in the statistical analysis as they were available at only one particle size and are included for comparison purposes.

All of the pulse flours had higher levels of the three anti-nutritional factors than the 100% CWRS straight grade flour. The 100% CWRS whole wheat flour had a high phytic acid content which was consistent with the findings of Peng et al (2010) who found that wheat bran had high levels of phytic acid. Despite the negative health effects that have been attributed to the anti-nutritional factors found in pulses, there is evidence that suggests that phenolics and phytic acid are also beneficial in protecting against cardiovascular diseases, cancer, diabetes, osteoporosis and hypertension (Carbonaro, 2011). More research needs to be done to determine if the possible beneficial effects of these components have health benefits.

4.2. Flour Blends

4.2.1. Composition

Each of the flour blends were analyzed for ash and protein while total dietary fibre was determined by calculation based on the data obtained for the 100% wheat and pulse flours.

4.2.1.1. Ash

The summary of ANOVA results for ash contents of blended flours are presented in Table 25. A three way interaction was observed between the pulse type, blend level and particle size.

Table 25: Summary of Analysis of Variance Results for Ash Content of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	2.9226681	4275.627	<0.0001
Blend Level (BL)	2	0.7194461	1052.491	<0.0001
Particle Size (PS)	1	0.0001307	0.3824	0.5839
PT * BL	4	0.0569421	41.6508	<0.0001
PT * PS	2	0.0003654	0.5345	0.5890
BL * PS	2	0.0020654	3.0215	0.0570
PT * BL * PS	4	0.0039730	2.9061	0.0299

Mean ash values are presented in Table 26. For each pulse type, regardless of particle size, the ash values increased as the amount of pulse flour in the blend increased. Ash values of the 100% pulse flours (Table 8) indicated that navy bean flour had the highest ash value which would explain why the navy bean flour blends

Table 26: Mean Protein and Ash Values of Blended Flours (db)[1]

	Ash (%)[2]		Protein (%)[3]	
	Fine	Coarse	Fine	Coarse
Whole Yellow Pea				
25%	1.06 ± 0.02[h]	1.07 ± 0.01[h]	18.46 ± 0.05[h]	18.53 ± 0.07[h]
30%	1.16 ± 0.01[g]	1.16 ± 0.01[g]	18.52 ± 0.49[h]	18.29 ± 0.56[h]
35%	1.26 ± 0.01[e]	1.24 ± 0.01[ef]	19.07 ± 0.01[g]	19.08 ± 0.04[g]
Whole Green Lentil				
25%	1.12 ± 0.01[g]	1.13 ± 0.02[g]	19.57 ± 0.07[defg]	19.66 ± 0.03[cdef]
30%	1.21 ± 0.01[f]	1.21 ± 0.03[f]	20.13 ± 0.16[abv]	20.02 ± 0.04[bcd]
35%	1.33 ± 0.01[d]	1.33 ± 0.03[d]	20.46 ± 0.13[ab]	20.54 ± 0.08[a]
Whole Navy Bean				
25%	1.44 ± 0.01[c]	1.44 ± 0.02[c]	19.45 ± 0.08[efg]	19.20 ± 0.18[fg]
30%	1.64 ± 0.03[b]	1.64 ± 0.01[b]	19.98 ± 0.15[bcd]	19.80 ± 0.04[cde]
35%	1.77 ± 0.01[a]	1.79 ± 0.03[a]	20.14 ± 0.32[abc]	19.98 ± 0.19[abcd]

1 Results are the means of 2 measurements ± SD.
23 Means with the same letter in the same column are not statistically different ($p \leq 0.05$).

have the highest ash values, followed by green lentil and yellow pea flour blends. Although a three way interaction involving particle size was observed, there was no significant difference due to particle size for any pulse type, pulse level combination. This interaction reflects the fact that fine flours containing 35% yellow pea and 30% green lentil were significantly different, but similar differences were not seen for the coarse flours. Therefore, although these differences indicate there is a three way interaction, for practical purposes, particle size did not seem to have an effect on the ash values of the blended flours.

4.2.1.2. Protein

Similar to the results for ash, the protein content of the blended flours increased as the amount of pulse flour added to the blend increased. The summary of the ANOVA results for protein contents are presented in Table 27, while mean protein values can be seen in Table 26.

Table 27: Summary of Analysis of Variance Results for Protein Content of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	26.338158	329.4558	<0.0001
Blend Level (BL)	2	6.793825	84.9818	<0.0001
Particle Size (PS)	1	0.077356	1.9352	0.1699
PT * BL	4	1.078042	6.7424	0.0002
PT * PS	2	0.103703	1.2972	0.2817
BL * PS	2	0.103603	1.2959	0.2820
PT * BL * PS	4	0.075364	0.4714	0.7565

A significant interaction was observed between pulse type and blend level. As the level of pulse flour increased, there was a subsequent increase in protein content, which occurred for all pulse flours (Table 26). Particle size, alone or as part of an interaction, had no significant effect on protein content ($p \leq 0.05$) of the pulse flours. The protein levels were consistent with the results found for the 100% pulse flours which showed that green lentil flour had the highest protein content followed by navy bean flour and yellow pea flours.

An advantage to blending the pulse flours with the wheat flour is that it creates a more complete protein. Wheat flour contains low levels of the amino acid lysine, which are rich in pulse flours (Zhao et al, 2005). By blending wheat flour with pulse flours using a ratio of 3:1 (Pulse Canada, personal communication, October, 2011), the amino acid profile of foods made with these flour blends are improved (Zhao et al, 2005) and offer consumers a complete protein. This is of significant importance to those who lack animal protein in their diet by choice or due to location and/or economics.

4.2.1.3. Total Dietary Fibre

Total dietary fibre contents of the blended flours were determined by calculation based on the dietary fibre content of the 100% wheat and pulse flours. The results are presented in Table 28. As expected, the total dietary fibre content, including soluble and insoluble fibre, increased as the level of pulse flour increased in the blend since higher levels of dietary fibre were found in the pulse flours compared to the wheat flour. As previously noted, the effect of particle size was not evaluated since it was not expected to influence the level of total dietary fibre in the flour blend.

Table 28: Total Dietary Fibre Content of Blended Flours (db)[1]

	Total Fibre (%)	Insoluble Fibre (%)	Soluble Fibre (%)
Whole Yellow Pea			
25%	5.20	4.3	0.95
30%	5.81	4.8	1
35%	6.40	5.4	1.05
Whole Green Lentil			
25%	4.60	3.8	0.85
30%	5.10	4.2	0.88
35%	5.64	4.7	0.91
Whole Navy Bean			
25%	6.40	4.6	1.8
30%	7.30	5.3	2
35%	8.10	6.0	2.2

[1] Results based on calculations.

Food products with a high fibre content offer a nutritional benefit to consumers. In Canada, a food can be labelled a source of fibre if it contains 2 g or more per serving, a high source of fibre if it contains 4 g or more, and a very high source if it contains 6 g or more of fibre (Canadian Food Inspection Agency (CFIA), 2011).

The addition of pulse flours has increased the nutritional value of a variety of food applications. Wood (2009) added chickpea flour to spaghetti and observed an increase in protein content as the amount of chickpea flour increased while Petitot et al (2010) added split pea and fababean flours to pasta and saw an increase in protein, dietary fibre, vitamins and minerals. Hung & Nithianandan (1993) also reported an increase in total dietary fibre with the addition of pulse flours. Increases in nutritional characteristics are dependent on the type of pulse being used in formulation as well as the level of pulse flour being incorporated. Although the nutritional content of the noodles in this study were not analyzed, sample nutrition labels, done by calculation can be seen for the 35% pulse noodles made with fine flours (Appendix F). An increase in both protein and fibre were found in the pulse noodles compared to the noodles made with 100% CWRS straight grade flour. Noodles made with the pulse flours (at 35% substitution) would be considered very high sources of fibre.

4.2.2. Functional Properties

4.2.2.1. Pasting Properties

As was done with the 100% pulse flours, the RVA was used to evaluate pasting characteristics of all of the blended flours. Peak viscosity, breakdown and setback were determined on the blended flours as all of these parameters have been correlated with noodle firmness (Bhattacharya & Corke, 1996). For peak viscosity, the summary of ANOVA is presented in Table 29. There was no interaction effect observed between the factors; however, main effects were observed for both pulse type and blend level. Mean peak viscosity values for all treatments can be seen in Appendix G.

Table 29: Summary of Analysis of Variance Results for Peak Viscosity of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	6239.3611	133.9132	<0.0001
Blend Level (BL)	2	6807.8611	146.1147	<0.0001
Particle Size (PS)	1	53.3889	2.2917	0.1359
PT * BL	4	128.3889	1.3778	0.2539
PT * PS	2	5.0278	0.1079	0.8979
BL * PS	2	93.8611	2.0145	0.1433
PT * BL * PS	4	24.7223	0.2653	0.8990

The mean values of peak viscosity for the blended flours by pulse type can be seen in Figure 2a and by blend level in Figure 2b. When the 100% pulse flours were analyzed, the navy bean flours had the lowest peak viscosity, but when blended with wheat, the navy bean flour blends had the highest peak viscosity of all the blended flours (Figure 2a). For all three pulse types, as the blend level increased, there was a decrease in peak viscosity (Figure 2b).

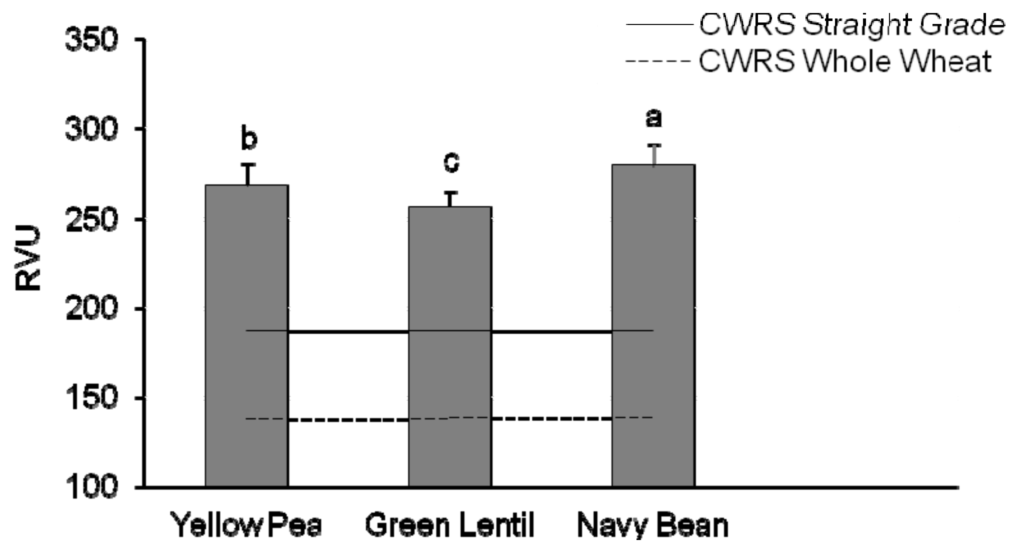

Figure 2a. Mean Peak Viscosity Values of Blended Flours by Pulse Type. Bars with the same letter have no significant difference ($p \leq 0.05$)

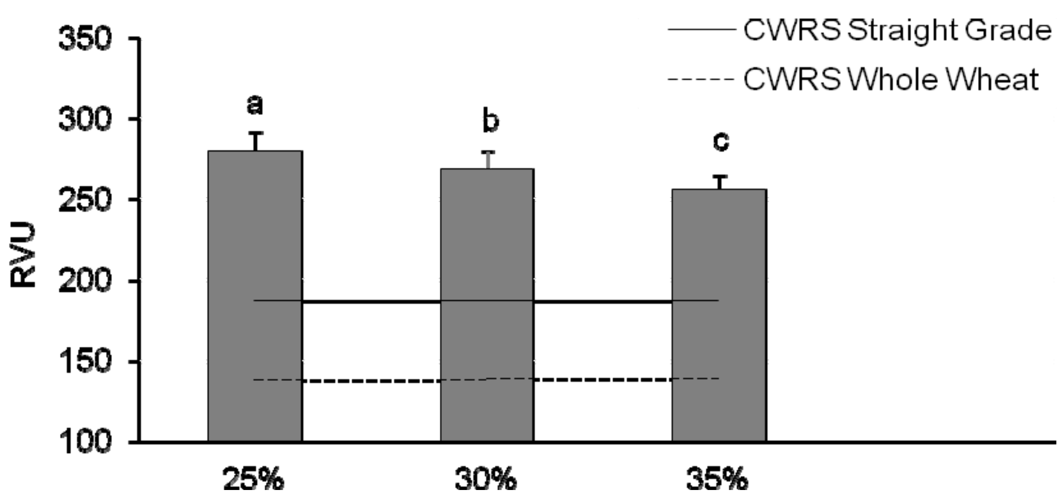

Figure 2b. Mean Peak Viscosity Values of Blended Flours by Blend Level. Bars with the same letter have no significant difference ($p \leq 0.05$)

The peak viscosity values of the 100% pulse flours were lower than the CWRS wheat flour control and ranged from 115.5 to 176 RVU. Peak viscosities for all of the pulse flour blends were much higher than the 100% CWRS straight grade and whole wheat flours (187 RVU and 138 RVU respectively) and, in some cases, were more than doubled compared to the peak viscosity of the same pulse flour that was used in the blend. As previously stated, higher peak viscosities have been associated with softer noodle texture (Ross & Crosbie, 2010) which suggests that noodles made with these flour blends could have a softer texture than those made using the 100% CWRS straight grade.

Wood (2004) observed higher peak viscosities in chickpea semolina blends when compared to a durum semolina control. The higher peak viscosities were attributed to higher water binding capacities of the starches in the blended flours (Wood, 2004). Wood (2004) also made reference to the non-starch polysaccharides (NSPs) that are high in pulse flours. NSPs are a major component of dietary fibre (Brennan & Tiwari, 2011) and could account for the increased water binding capacity of the blended flours. As previously mentioned, the navy bean flour had the highest insoluble fibre content, followed by the yellow pea and green lentil (Table 9), which is the same trend observed for the peak viscosity. The composition of the blended flours could be a factor in the increased peak viscosities observed here

The summary of ANOVA for breakdown is presented in Table 30. There was a significant interaction observed between pulse type and blend level. There were no significant effects ($p \geq 0.05$) associated with particle sizes. Mean breakdown values of the blended pulse flours are presented in Figure 3. Mean breakdown values for all treatments are provided in Appendix H.

Table 30: Summary of Selected Analysis of Variance Results for Breakdown of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	599.0833	34.4888	<0.0001
Blend Level (BL)	2	3116.3333	179.4051	<0.0001
Particle Size (PS)	1	24.5000	2.8209	0.0988
PT * BL	4	180.3333	5.1908	0.0013
PT * PS	2	7.5833	0.4366	0.6485
BL * PS	2	25.3333	1.4584	0.2416
PT * BL * PS	4	7.8333	0.2255	0.9230

For each pulse type, the breakdown values decreased as the blend levels increased. As was seen with peak viscosities, the breakdown values of the pulse flours increased significantly ($p \geq 0.05$) compared to the analysis done on the 100% pulse flours. As breakdown is the difference between peak and final viscosity (CIGI, 2010), this result was somewhat expected based on the high peak viscosities of the blended samples. All of the breakdown values of the blended pulse flours are higher than the CWRS straight grade flour (71 RVU). Higher breakdown values were also observed by Wood (2004) with the addition of chickpea flour; however, Wood (2004) observed an increase in breakdown as blend level increased.

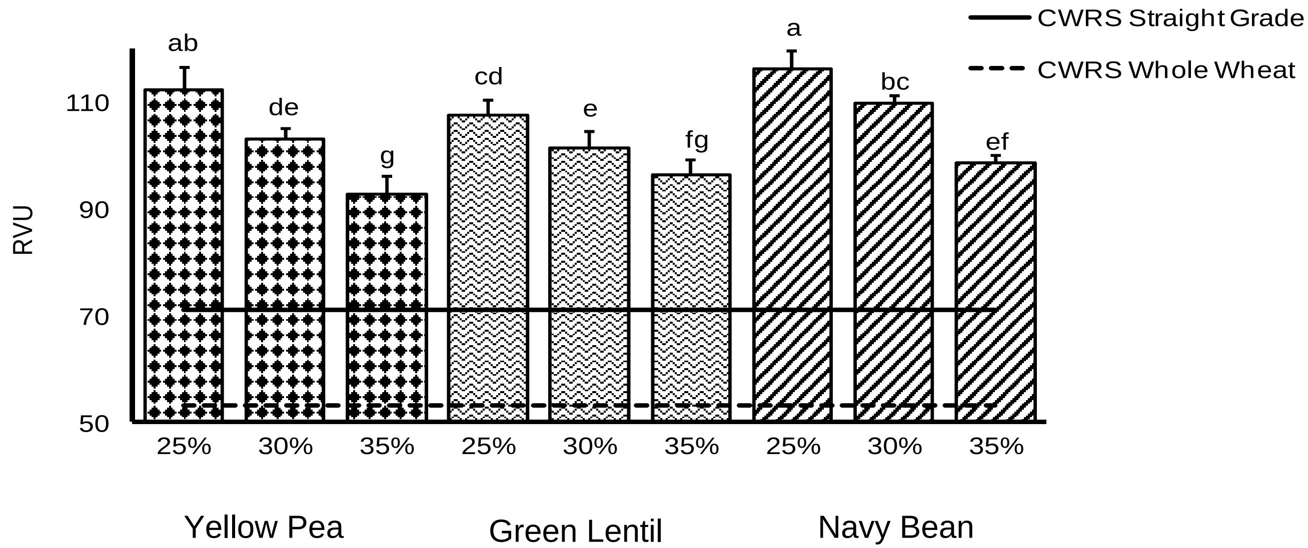

Figure 3. Mean Breakdown Values of Blended Flours by Pulse Type and Blend Level. Bars with the same letter have no significant difference ($p \leq 0.05$)

Lastly, the setback values of the blended pulse flours were analyzed. The summary of ANOVA is presented in Table 31. Significant main effects for pulse type and blend level were found for the setback values. Mean setback values based on pulse type can be seen in Figure 4a while the mean setback values based on blend level are presented in Figure 4b. Mean setback values for all treatments can be seen in Appendix I.

Table 31: Summary of Analysis of Variance Results for Setback of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	564.08333	42.0725	<0.0001
Blend Level (BL)	2	85.75000	6.3957	0.0032
Particle Size (PS)	1	0.00000	0.0000	1.0000
PT * BL	4	47.16667	1.7590	0.1506
PT * PS	2	11.58333	0.8640	0.4272
BL * PS	2	7.58333	0.5656	0.5713
PT * BL * PS	4	13.33333	0.4972	0.7378

As was seen with peak viscosity and with breakdown, the values for setback of the blended pulse flours were greater than the 100% pulse flours. As previously mentioned, higher setback values are associated with syneresis (Kaur et al, 2007) which is the release of water from the starch during cooling. Navy bean blended flours had the highest setback values, while green lentil blends had the lowest (Figure 4a). As the blend levels increased, the setback values decreased (Figure 4b), however were only significantly different at 35%.

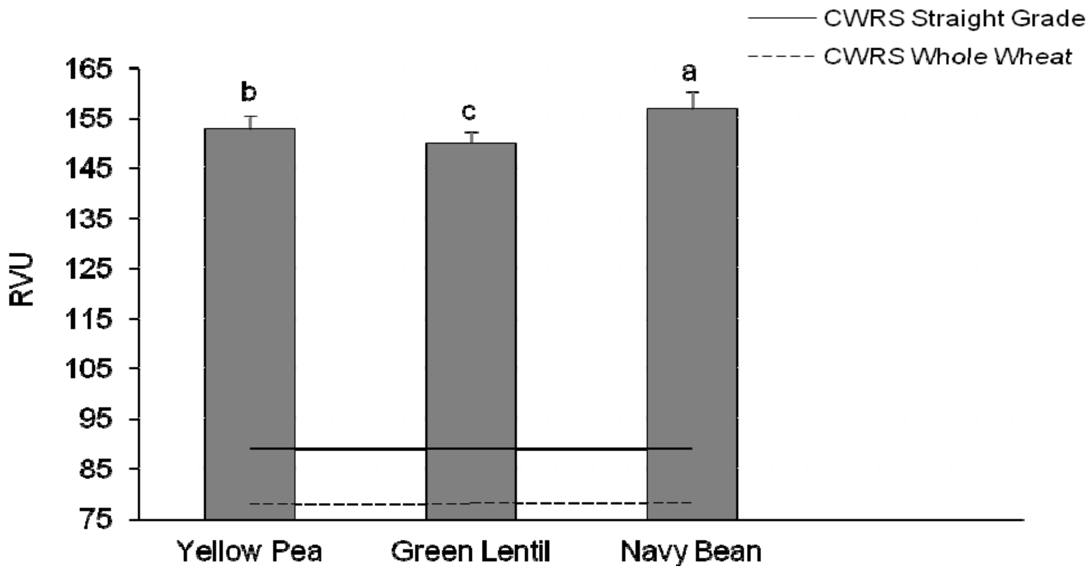

Figure 4a. Mean Setback Values of Blended Flours by Pulse Type. Bars with the same letter have no significant difference ($p \leq 0.05$)

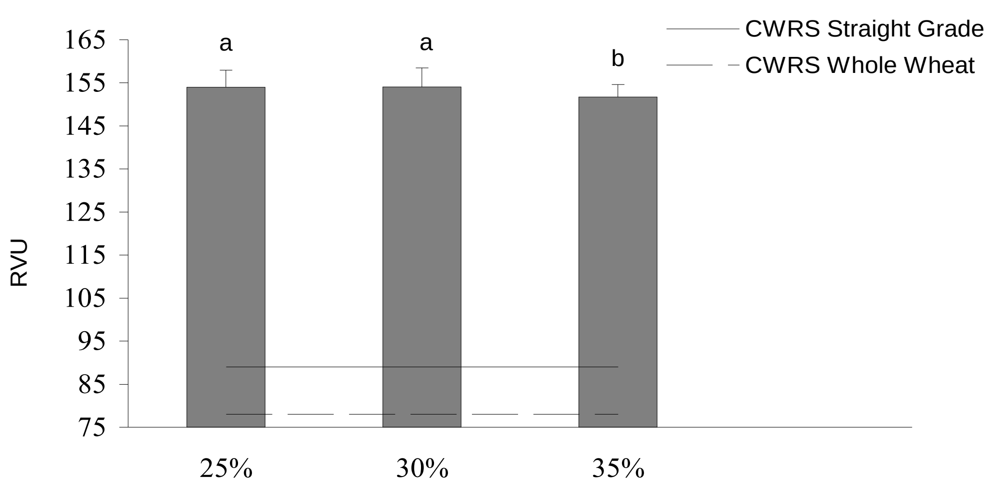

Figure 4b. Mean Setback Values of Blended Flours by Blend Level. Bars with the same letter have no significant difference ($p \leq 0.05$)

The differences observed among the RVA results, could be indicators of the end quality characteristics of the noodles. There were unexpected increases observed in peak viscosities as well as breakdown and setback values when pulse flours were blended with wheat flours suggesting that there is a synergistic relationship occurring between the two different sources of flour. These increases in pasting properties could be an indication that the noodles made with pulse flours could have a softer texture which has been previously observed by other researchers (Ross & Crosbie, 2010)

4.2.2.2. Water Absorption Capacity

All of the blended flours were analyzed for WAC. The summary of the ANOVA analysis for WAC of all blended flours can be seen in Table 32.

Table 32: Summary of Analysis of Variance Results for Water Absorption Capacity of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	0.33011026	19.2941	<0.0001
Blend Level (BL)	2	0.03500755	2.0461	0.1391
Particle Size (PS)	1	0.00084598	0.0989	0.7544
PT * BL	4	0.02314144	0.6763	0.6114
PT * PS	2	0.00094896	0.0555	0.9461
BL * PS	2	0.01723446	1.0073	0.3720
PT * BL * PS	4	0.01109177	0.3241	0.8606

Only pulse type had a significant effect on WAC. The mean values for WAC of the blended flours can be seen in Table 33. The WAC of the blended flours were all lower than in the corresponding 100% pulse flours reported in Table 16. The navy bean blended flours had a significantly higher WAC than yellow pea flour blends. All of the blended flours had higher WAC than the 100% CWRS straight grade and 100% whole wheat flours (Table 16). The lack of effect due to particle size is most likely a result of the wheat flour only being one particle size and comprising the majority of the blend.

Table 33: Mean Water Absorption Capacity of Blended Flours[1]

	WAC (g/g)[2]
Whole Yellow Pea	0.091± 0.117[b]
Whole Green Lentil	1.044± 0.084[a]
Whole Navy Bean	1.061± 0.057[a]

[1] Means of all measurements ± SD of blend levels and particle sizes.
[2] Means followed by the same letter are not significantly different ($p \leq 0.05$).

The increase in WAC of blended pulse flours could be due to the higher fibre content. Sosulski & Wu (1988), Wang et al (2002) and Rossell et al (2006) all observed increased water absorbing properties of bread products when pulse fibres were incorporated.

4.2.2.3. Colour

As was done with the 100% pulse flours, colour was measured for all of the blended flours and was reported using L*, a* and b* values. The summary of the ANOVA analysis performed on the colour values can be seen in Tables 34-36. Three way interaction effects were observed for all three of the colour parameters (L*, a*, b*).

Table 34: Summary of Analysis of Variance Results for L* Values of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	203.60297	3531.651	<0.0001
Blend Level (BL)	2	30.87381	535.5302	<0.0001
Particle Size (PS)	1	0.00190	0.0660	0.7983
PT * BL	4	3.10992	26.9720	<0.0001
PT * PS	2	0.04620	0.8014	0.4540
BL * PS	2	0.63948	11.0922	<0.0001
PT * BL * PS	4	0.37201	3.2264	0.0191

Table 35: Summary of Analysis of Variance Results for a* Values of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	81.940578	62145.94	<0.0001
Blend Level (BL)	2	0.001319	1.0007	0.3743
Particle Size (PS)	1	0.045000	68.2584	<0.0001
PT * BL	4	0.594439	225.4192	<0.0001
PT * PS	2	0.016900	12.8174	<0.0001
BL * PS	2	0.017908	13.5822	<0.0001
PT * BL * PS	4	0.009767	3.7037	0.0098

Table 36: Summary of Analysis of Variance Results for b* Values of Blended Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	1013.2443	14701.07	<0.0001
Blend Level (BL)	2	23.5779	342.0901	<0.0001
Particle Size (PS)	1	0.0238	0.6916	0.4093
PT * BL	4	9.4253	68.3756	<0.0001
PT * PS	2	0.0501	0.7267	0.4882
BL * PS	2	0.6194	8.9871	0.0004
PT * BL * PS	4	0.9160	6.6449	0.0002

The mean values for the L* values of the blended flours can be seen in Figure 5. There were no significant differences ($p \geq 0.05$) between the yellow pea and the navy bean flour blends when the same blend level and particle size were compared. For the green lentil blends, the L* values were significantly lower than both the yellow pea and navy bean flours. These results are consistent with the results of the 100% pulse flours (Table 18). Regardless of pulse type, as blend levels increased, L* values decreased, indicating that the addition of pulse flours resulted in a darker flour. All blends were darker than the CWRS straight grade flour which had an L* value of 85.26 and lighter than the CWRS whole wheat flour which had an L* value of 72.90. The only significant difference observed for particle size was found between the 30% fine and coarse green lentil flours.

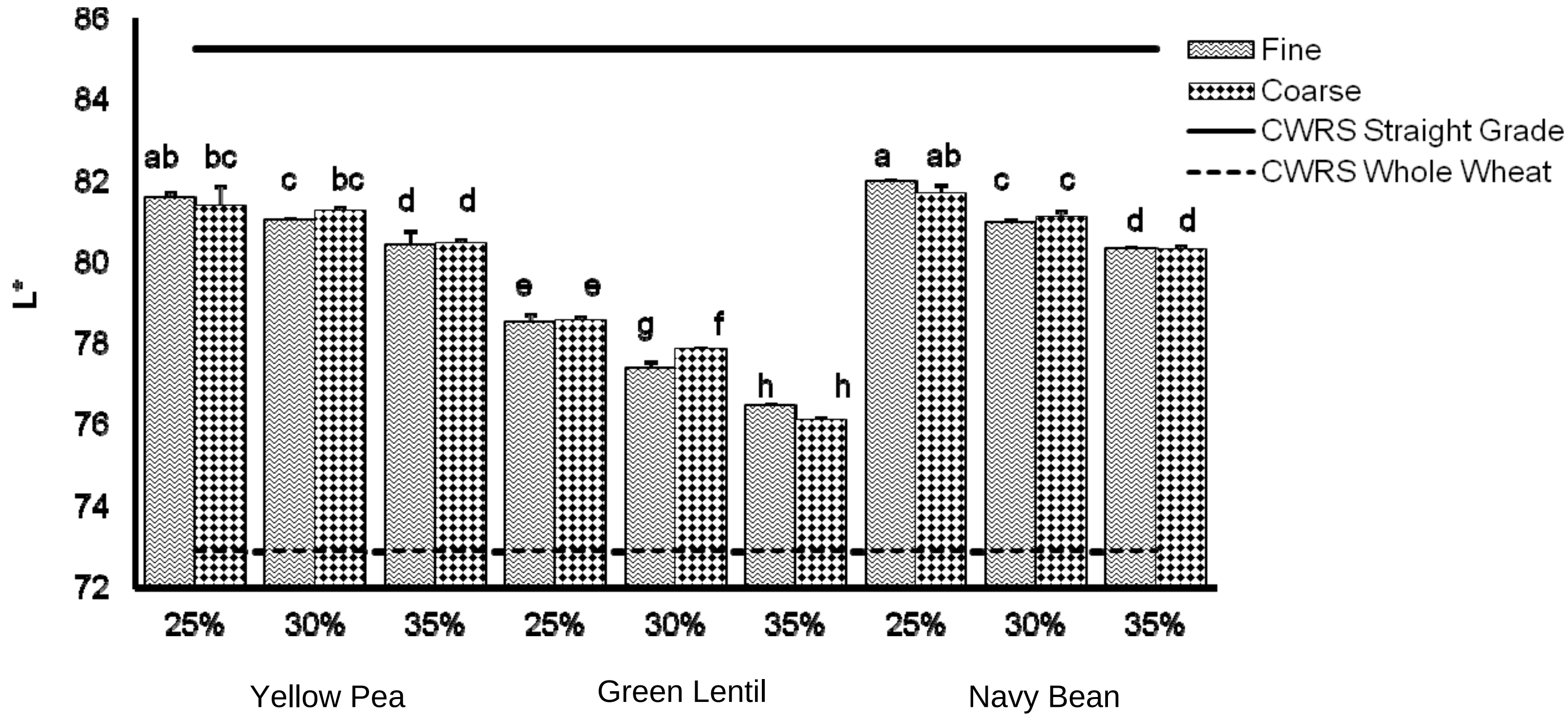

Figure 5: Mean L*Values of Blended Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

The mean a* values of the blended flours can be seen in Figure 6. There was a three way interaction observed between the pulse type, blend level and particle size. Among all three pulse types, the yellow pea blends had a* values closest to that of the CWRS straight grade flour. The only significant differences observed among the yellow pea blends was between the 25% fine and coarse blends.

Green lentil blends had the lowest a* values which ranged between -2.22 and -2.47 indicating that of the three pulse types used, green lentil was in fact, the most green. Significant differences in particle size were observed between the coarse and fine green lentil noodles for both the 25 and 30% blend levels. Navy bean blends had positive a* values indicating that they were more red than green. The values for the navy bean blends ranged between 0.12 and 0.42 and increased as the level of navy bean flour increased**.** No particle size effect was seen for the navy bean flours.

Similarly to a* values, there was a three way interaction between pulse type, blend level and particle size for the b* value of the flour blends. Mean b* values can be seen in Table 7. The navy bean blends were the only flours that had b* values similar to both the straight grade and whole wheat flours and they did not differ among blend levels or particle size. Both yellow pea and green lentil flour blends increased significantly ($p \geq 0.05$) in yellowness as the blend levels increased, however the only difference observed between particle size was found for the 35% green lentil blends. Yellow pea and green lentil blends had much higher b* values than both the CWRS straight grade and CWRS whole wheat flours.

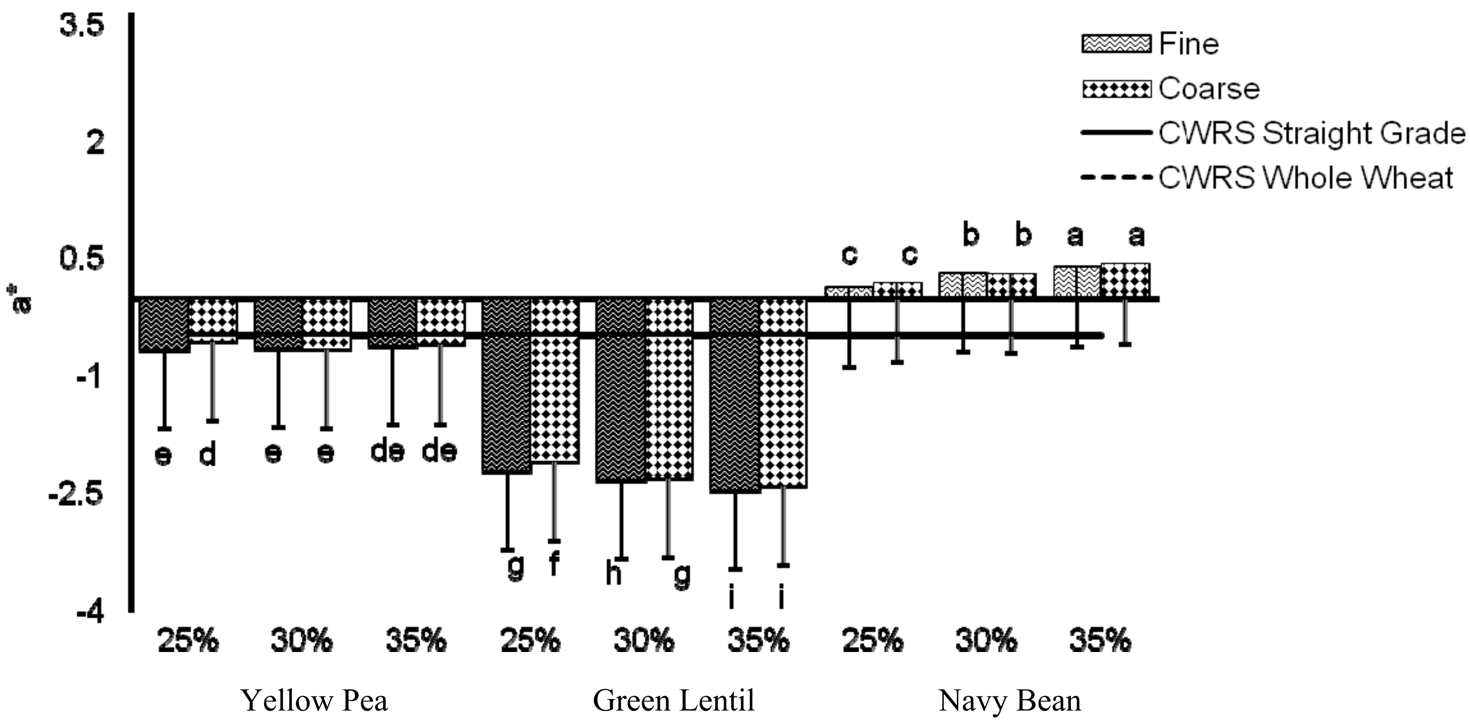

Figure 6: Mean a* Values of Blended Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

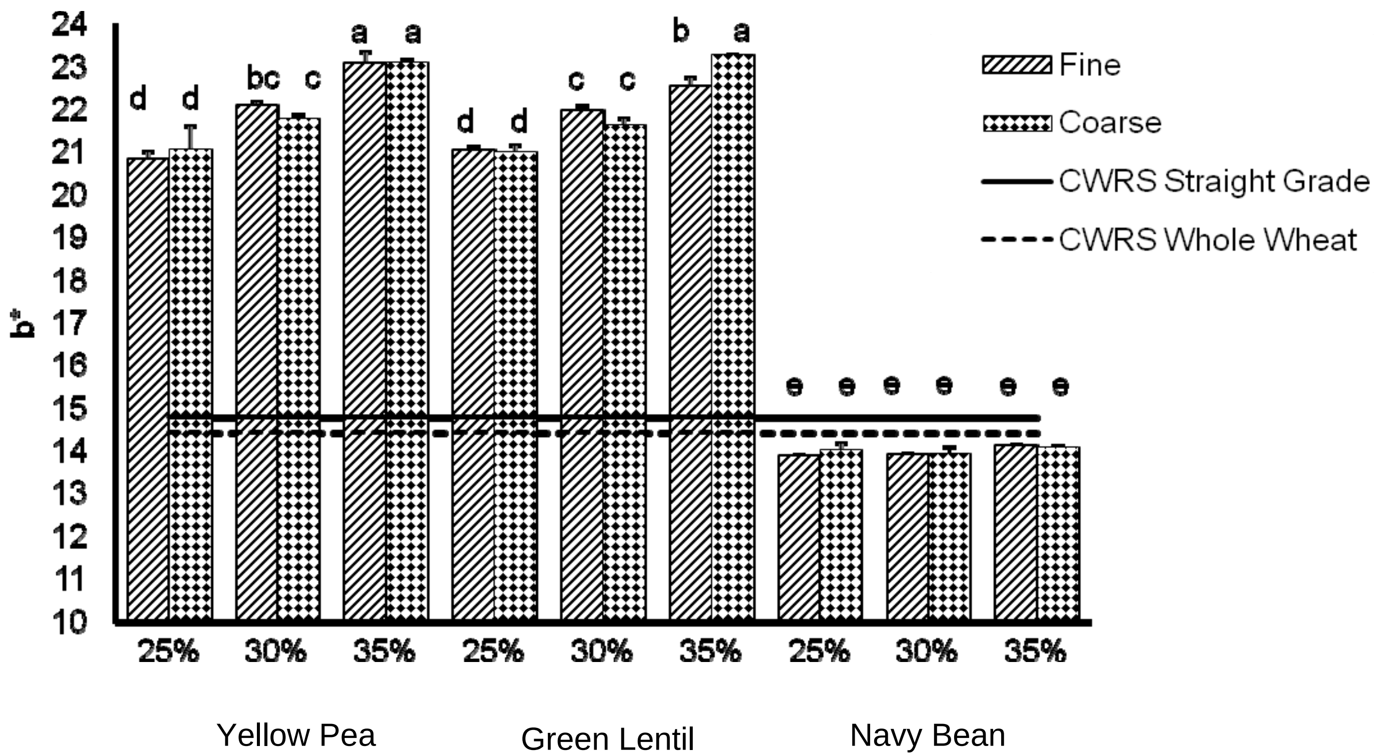

Figure 7: Mean b* Values of Blended Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

For all three colour parameters evaluated, there was a three way interaction between pulse type, blend level and particle size. Differences in pulse type and particle size were also observed for the 100% pulse flours. There were obvious colour differences between the yellow pea, green lentil and navy bean flours that are noticeable not only by instrumental evaluation but also by visual examination. The colour differences observed among the pulse flour blends can be attributed to variations in phenolic content which affects pigmentation (Naczk & Shahidi, 2004). Changes in colour based on blend level were consistent with the amount of pulse flour incorporated into each blend.

Lastly, some minor differences in colour were observed between the coarse and fine flours. As previously stated, differences in colour as a result of particle size could be a result of the fine flours inability to dissolve, resulting in colour differences when measured as a slurry.

4.3. Asian White Salted Noodle Evaluation

4.3.1. Noodle Formulation

The noodle formulations of the pulse noodles differed not only in regards to the flours that were being used but also with the amount of distilled water incorporated into the dough mixture. Determining the correct amount of water to use in a dough mixture is important. Dough mixtures that do not contain enough water result in a streaky dough sheet, are prone to surface flaking, and produce weak noodles that are susceptible to breakage when hung to dry (Hou et al, 2010). Too much water causes problems when sheeting the dough due to the overdevelopment of gluten (Hou et al, 2010). The most common methods to determine optimal hydration of the noodle dough are through operator experience and handfeel (Hatcher et al, 2002).

For the 100% CWRS straight grade noodles, 32% water was added to the noodle formulation. The addition of pulse flours decreased the water absorption by up to 7% (Table 5). As the amount of pulse flour increased, the amount of water added to the dough mixture decreased. These levels were determined through operator experience. Jeffers et al (1979) also observed a decrease in salted water needed for the noodle doughs when incorporating pulse flours. The reduced water requirement could be due to the decreased gluten content of the blended flours.

4.3.2. Optimum Cooking Times (OCT)

Knowledge of OCT for any food product is important for a consumer. Cooking noodles to their OCT will ensure they maintain high quality characteristics when being consumed. The summary of ANOVA results for OCT can be seen in Table 37. The only factor that had a significant affect on OCT was pulse type.

Table 37: Summary of Analysis of Variance Results for OCT of Dried White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	13.347222	49.600	<0.0001
Blend Level (BL)	2	0.010417	0.774	0.7832
Particle Size (PS)	1	0.006944	0.0516	0.8222
PT * BL	4	0.020833	0.0774	0.9257
PT * PS	2	0.513889	1.9097	0.1700
BL * PS	2	0.093750	0.6968	0.4121
PT * BL * PS	4	0.187500	0.6968	0.5080

Only slight variations in cooking times (up to 30 sec) were found among the noodles made within each pulse type. Therefore, an average cooking time was established according to pulse type (Table 38).

Table 38: Optimum Cooking Times of Dried White Salted Noodles made with Wheat and Pulse Flours

Noodle Type	Optimum Cooking Time (min)
CWRS Straight Grade	7.5
CWRS Whole Wheat	5.5
Yellow Pea	7.5
Green Lentil	8.5
Navy Bean	7.0

The CWRS whole wheat noodles had the shortest cooking time, followed by navy bean, CWRS straight grade, yellow pea and green lentil noodles. Park & Baik (2004) examined the effects of protein and amylose content of different wheats and determined that protein content had an effect on OCT. Noodles made with higher protein wheats had longer cooking times (Park & Baik, 2004). Although the noodles made with green lentil had both the highest protein content and the longest cooking time, navy bean had the next highest protein content yet had the lowest OCT of all the pulse noodles. In addition to protein content, starch content and specifically amylose content has been shown to have an effect on OCT. Park & Baik (2004) observed that reduced amylose contents resulted in reduced cooking times of white salted noodles made with wheat.

Research is limited on the optimum cooking times of noodles made with pulse flours. The literature that exists on optimum cooking times of noodles correlates it to protein and starch contents of various wheat flours (Moss et al, 1987, Park & Baik, 2004). Although pulse flours have higher protein contents, they lack gluten, the protein found in wheat. This makes a comparison between wheat and pulse noodles difficult. Composition undoubtedly plays a role in the cooking times of noodles, therefore more research needs to be done to determine how the addition of pulse flours affects OCT.

4.3.3. Noodle Thickness

Prior to being cooked for texture analysis the noodles thickness was measured. The summary of ANOVA results for thickness can be seen in Table 39.

Table 39: Summary of Analysis of Variance Results for Thickness of Cooked White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	0.03600278	43.3711	<0.0001
Blend Level (BL)	2	0.00941944	11.8705	<0.0001
Particle Size (PS)	1	0.00000139	0.0035	0.9530
PT * BL	4	0.00355556	2.2404	0.0767
PT * PS	2	0.00048611	0.6126	0.5457
BL * PS	2	0.00030278	0.3816	0.6846
PT * BL * PS	4	0.00117222	0.7386	0.5698

Significant main effects for both pulse type and blend level were observed. Tables 40a and 40b illustrate the differences observed between pulse type and blend level respectively. All of the pulse noodles were thicker than the straight grade noodles. There were no significant differences between the green lentil and navy bean noodles, however, the yellow pea noodles were significantly less thick than the other pulse noodles. The increased thickness is likely a result of the decreased water in the noodle formulation at the higher blend level. This results in less moisture being removed in drying and therefore producing a thicker noodle.

Table 40a: Mean Thickness (mm) Values of Dried White Salted Noodles made with Pulse Flours by Pulse Type[1]

	Thickness (mm)[2]
100% CWRS Straight Grade	1.08 ± 0.017
100 % CWRS Whole Wheat	1.18 ± 0.013
Whole Yellow Pea	1.11 ± 0.02[b]
Whole Green Lentil	1.16 ± 0.02[a]
Whole Navy Bean	1.17 ± 0.03[a]

[1] Means of all measurements ± SD of blend levels and particle sizes.
[2] Means followed by the same letter are not significantly different ($p \leq 0.05$)

Table 40b: Mean Thickness (mm) Values of Dried White Salted Noodles made with Pulse Flours by Blend Level[1]

	Thickness (mm)[2]
100% CWRS Straight Grade	1.08 ± 0.017
100 % CWRS Whole Wheat	1.18 ± 0.013
25%	1.14 ± 0.03[b]
30%	1.14 ± 0.03[b]
35%	1.16 ± 0.03[a]

[1] Means of all measurements ± SD of pulse types and particle sizes.
[2] Means followed by the same letter are not significantly different ($p \leq 0.05$)

4.3.4. Noodle Firmness

Firmness is one of the most important textural parameters influencing the quality of white salted noodles (Park & Baik, 2002). The desired firmness of noodles varies depending on the geographical region of where the noodles are being consumed. Firmness was measured on all noodles once they had been cooked according to their predetermined OCT. The summary of ANOVA results for instrumental analysis of firmness of the pulse noodles are presented in Table 41. A significant interaction was observed between both pulse type and blend level. Particle size was found to have no significant effect on firmness ($p \leq 0.05$). Mean values of firmness for all treatments can be seen in Appendix J.

Table 41: Summary of Analysis of Variance Results for Firmness of Cooked White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	0.26646836	53.2442	<0.0001
Blend Level (BL)	2	0.00083544	0.1669	0.8467
Particle Size (PS)	1	0.00616050	2.4619	0.1225
PT * BL	4	0.06681131	6.6749	0.0002
PT * PS	2	0.00522808	1.0446	0.3588
BL * PS	2	0.00105833	0.2115	0.8101
PT * BL * PS	4	0.01854308	1.8526	0.1322

A two way interaction was observed between pulse type and blend level. This interaction can be seen in Figure 8. The green lentil noodles, which had the longest OCT (8.5 min) were the firmest noodles when measured using the texture analyzer and the 35% blend level had the highest firmness value. The 35% green lentil noodles were significantly different ($p \geq 0.05$) then both the yellow pea and navy bean noodles regardless of blend level. Generally, the firmness of the green lentil noodles seemed to increase as the blend levels increased, while the opposite trend was observed for the navy bean noodles in which the firmness decreased as the blend increased. The control noodles made with straight grade flour were similar in firmness to the yellow pea and navy bean noodles while the whole wheat noodles were the least firm of all the noodle samples.

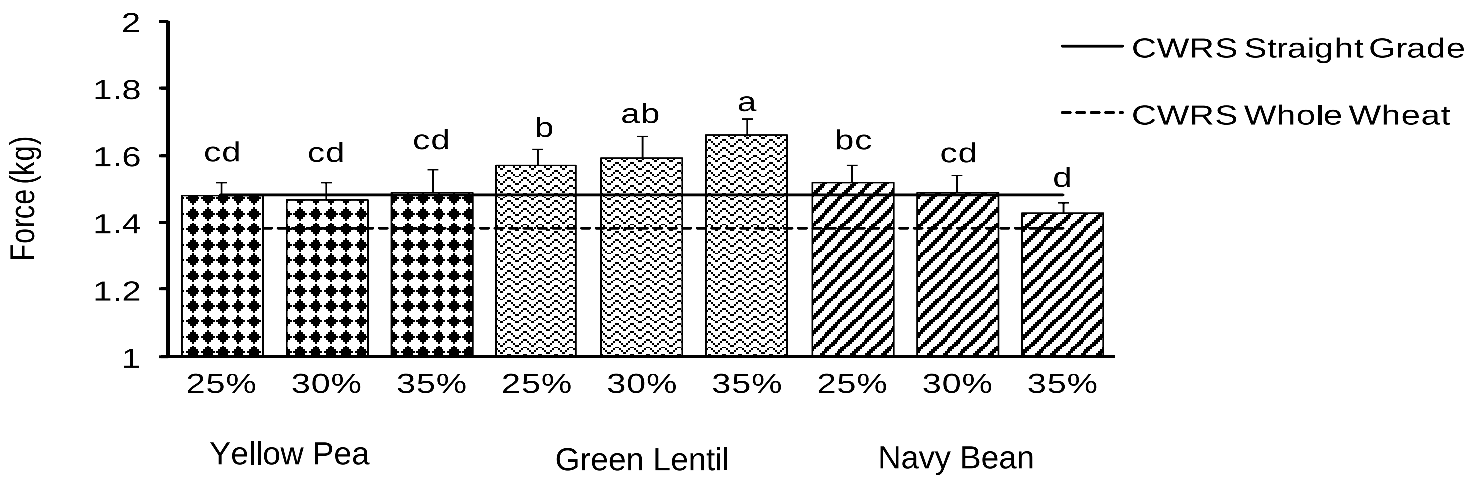

Figure 8: Mean Firmness Values for Dried White Salted Noodles made with Selected Pulse Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

The differences reflect the results from the RVA results from the blended flour analysis (Figure 2) where navy bean noodles had the highest peak viscosity, followed by yellow pea and green lentil. These differences are consistent with the work of Ross & Crosbie (2010) who stated that higher peak viscosities result in softer noodles.

Differences in texture have been observed by other researchers who have added pulse flours into noodle or pasta products. Chompreeda et al (1988) added cowpea and peanut flour using blends as high as 21% and saw a decrease in firmness as blend levels increased, but were still able to achieve favourable firmness scores in sensory evaluation. Hung & Nithianandan (1993) reported an increase in firmness of extruded noodles when supplemented with lupin and chickpea flours. Zhao et al (2005) and Bahnassey & Khan (1986) reported an increase in firmness when pulse flours were added to pasta formulations while Sabanis et al (2006) reported a decrease in firmness with the addition to chickpea flours in lasagna.

Wheats with higher protein content have been positively correlated with noodle firmness (Fu, 2008) and therefore protein content has been associated with firmness. Although pulse flours are higher in protein than wheat flours, they lack gluten, and are made up of storage proteins such as globulins, albumins, and glutelins (Roy et al, 2010). These differences in protein composition may have an effect on the firmness of the noodles resulting in differences observed between the noodles made with pulse flours compared to those made with wheat flour.

4.3.5. Dried Noodle Colour

Colour analysis was performed on both the dried and the cooked noodles in order to compare the effect that cooking had on the noodle colour. As was done with the flours, the noodles were evaluated using L*, a* and b* values. The summary of ANOVA results for all of the colour values of the dried noodles can be seen in Tables 42-44.

Table 42: Summary of Analysis of Variance Results for L* Values for Dried White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	658.33321	2049.676	<0.0001
Blend Level (BL)	2	1.85959	5.7897	0.0053
Particle Size (PS)	1	0.08405	0.5234	0.4725
PT * BL	4	5.87816	9.1506	<0.0001
PT * PS	2	1.29853	4.0429	0.0231
BL * PS	2	0.07331	0.2282	0.7967
PT * BL * PS	4	1.10596	1.7217	0.1586

Table 43: Summary of Analysis of Variance Results for a* Values for Dried White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	56.722336	2197.909	<0.0001
Blend Level (BL)	2	0.335219	12.9893	<0.0001
Particle Size (PS)	1	0.000450	0.0349	0.8526
PT * BL	4	0.495989	9.6094	<0.0001
PT * PS	2	0.023425	0.9077	0.4095
BL * PS	2	0.010975	0.4253	0.6558
PT * BL * PS	4	0.152800	2.9604	0.0277

Table 44: Summary of Analysis of Variance Results for b* Values for Dried White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	221.48354	421.5166	<0.0001
Blend Level (BL)	2	2.40569	4.5784	0.0146
Particle Size (PS)	1	0.03380	0.1287	0.7212
PT * BL	4	5.67344	5.3987	0.0010
PT * PS	2	7.56413	14.3957	<0.0001
BL * PS	2	0.32926	0.6266	0.5382
PT * BL * PS	4	1.96173	1.8667	0.1296

For the dried noodles, two way interactions between pulse type and blend level, and pulse type and particle size were observed for the L* values. The pulse type and blend level interaction can be seen in Figure 9a. The dried navy bean noodles had the highest L* values followed by the dried yellow pea noodles. This was the same trend observed for the L* values of the blended pulse flours. The dried green lentil noodles had the lowest L* values and became darker as the amount of pulse flour increased.

The two way interaction between pulse type and particle size on L* can be seen in Figure 9b. Although significant differences ($p \geq 0.05$) occurred among all of the coarse noodles and among all of the fine noodles, no differences due to particle size could be identified using the Tukey's test. Therefore, for the L* values of the dried noodles made with pulse flours, the role of particle size was of minor importance. Mean L* values for all treatments can be seen in Appendix K.

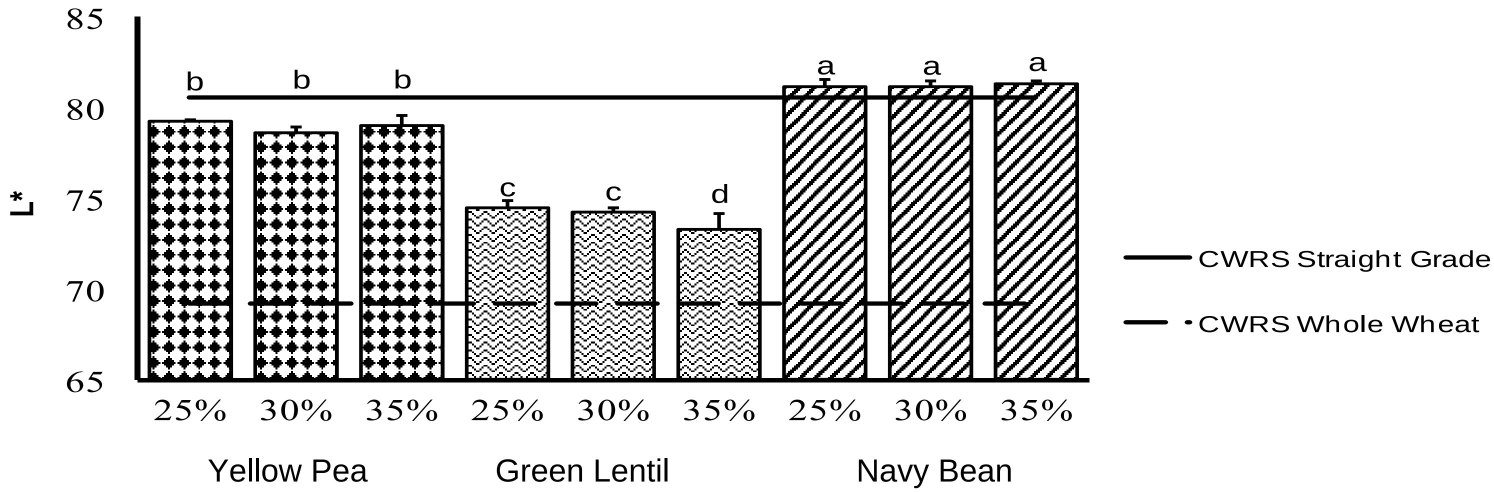

Figure 9a. Interaction Effect between Pulse Type and Blend Level for L* Values of Dried White Salted Noodles made with Selected Pulse Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

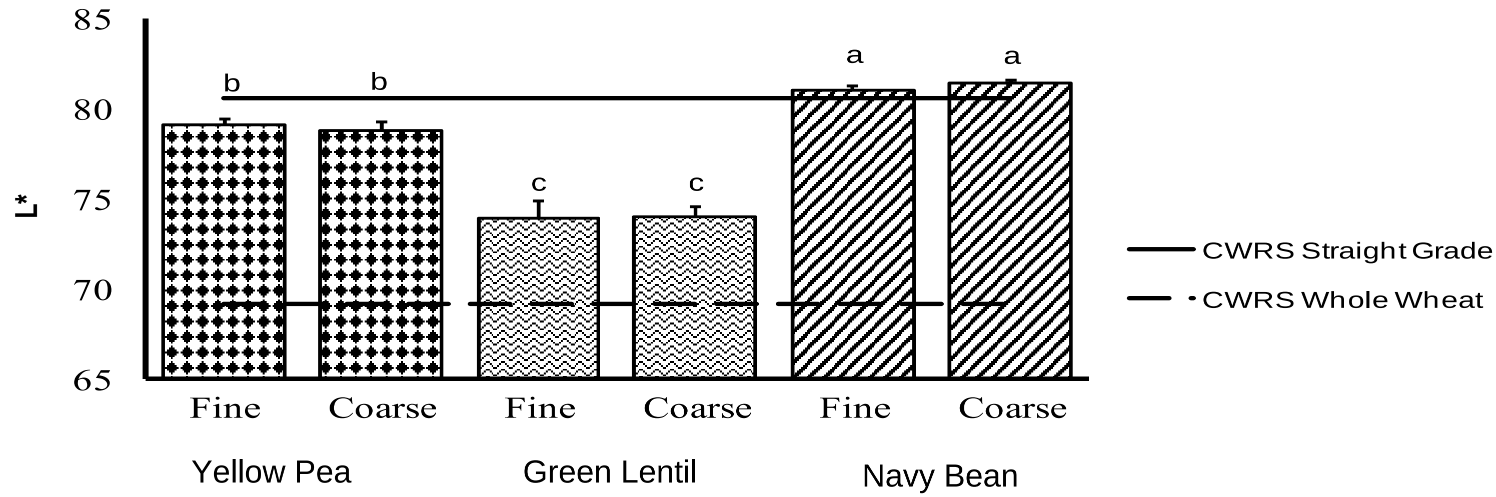

Figure 9b: Interaction Effect between Pulse Type and Particle Size for L* Values of Dried White Salted Noodles made with Selected Pulse Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

The dried navy bean noodles had a slightly higher L* value than the noodles made with 100% CWRS straight grade flour while both the yellow pea and green lentil flours were lower. Chompreeda et al (1988) observed a darkening of noodles when peanut and cowpea flours were introduced to noodles at different levels and became darker as blend levels increased. Petitot et al (2010) observed a darkening of dried pasta when split pea and faba bean flours were added. Petitot et al (2010) attributed the darkening of the pasta to higher ash values of the pulse flours.

A three way interaction was observed between pulse type, blend level and particle size for a* values of the dried noodles (Table 43). The mean a* values for the dried noodles can be seen in Figure 10. The noodles prepared with different pulses had significantly different ($p \geq 0.05$) a* values from one another. Both the yellow pea and the navy bean noodles had higher a* values than the 100% CWRS straight grade noodles, while amongst all the green lentil noodles, only the 25% coarse noodles did. Both navy bean and green lentil noodles decreased in a* values as the blend levels increased and significant differences ($p \geq 0.05$) were observed between the 25% and 35% flours. For green lentil noodles, these differences were seen with the coarse particle size only, while for navy bean this was seen for the fine particle size.

Zhao et al (2005) saw an increase in a* values with an increase in green lentil flour when added to pasta; however, Richlea lentils which are known to have a yellowish coloured cotyledon were used in that study and this could explain the difference in colours.

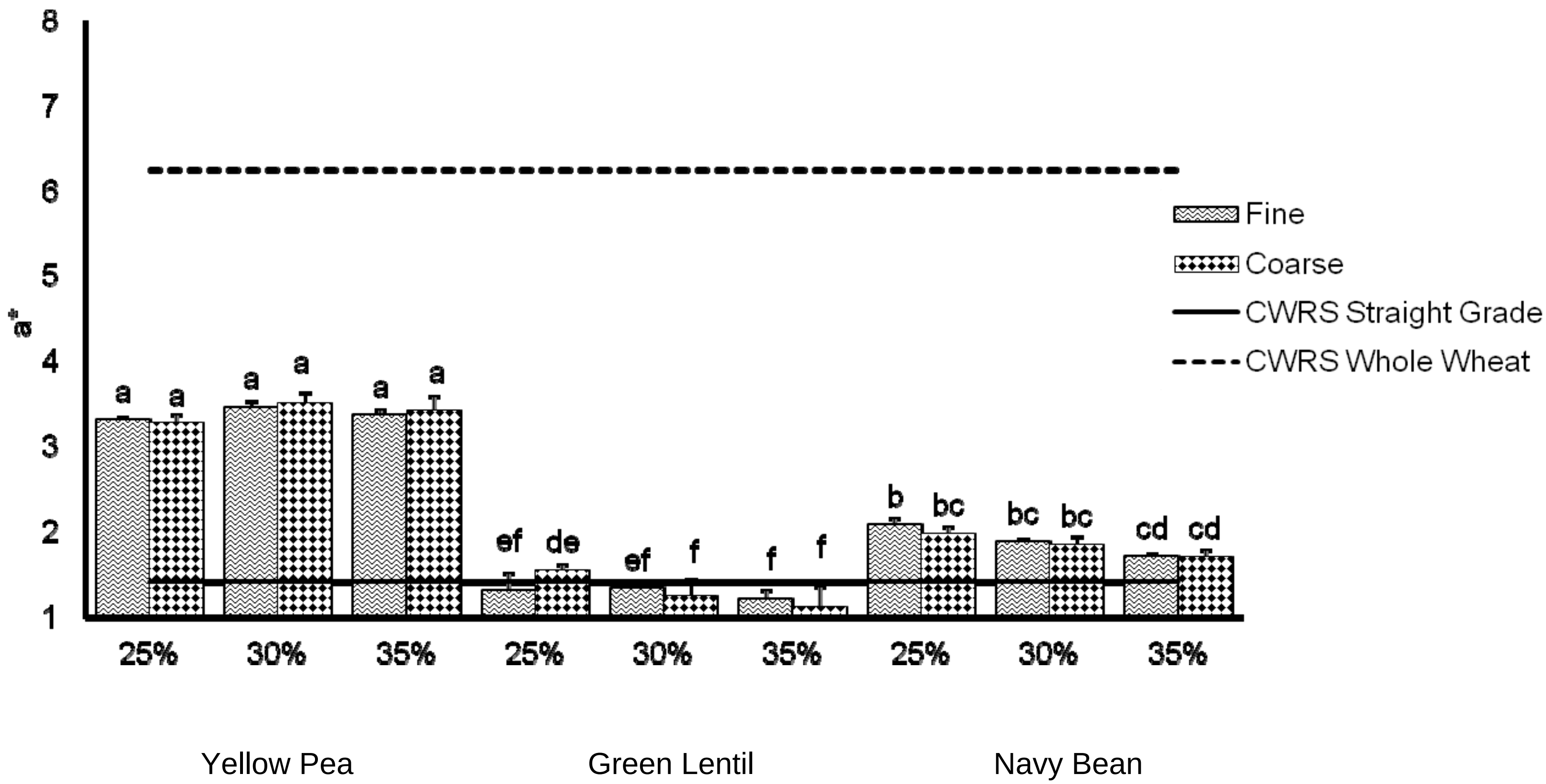

Figure 10: Mean a* Values for Dried White Salted Noodles made with Selected Pulse Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

Among the dried yellow pea noodles there were no significant differences in a* values ($p \geq 0.05$) regardless of blend level or particle size. All of the a* values were higher for the dried noodles in comparison to the blended flours used to make them. This is an indication that the processing or drying process had an effect on the end colour of the noodles. Changes during drying could be caused by the Maillard reaction (Petitot et al, 2010).

Two different interaction effects between pulse type and particle size and pulse type and blend level were observed for the b* values of the dried noodles (Table 44). Mean b* values for the dried noodles for all treatments can be seen in Appendix L. The first interaction was between pulse type and blend level and can be seen in Figure 11a while the other was between pulse type and particle size and is shown in Figure 11b. The b* values for navy bean noodles were significantly lower ($p \geq 0.05$) than both the green lentil and the yellow pea noodles. The only significant difference ($p \geq 0.05$) that was observed based on blend level was for the yellow pea noodles. The 30% yellow pea noodles were higher than both the 25 and 35% blends and were more similar to the values of the green lentil noodles.

For the second interaction between pulse type and particle size, significant differences were observed among the two particle sizes of navy bean noodles. The navy bean noodles also had the lowest b* values of all the pulse types indicating that they were the least yellow of the three pulse types. No significant differences ($p \geq 0.05$) were observed among the green lentil or yellow pea noodles based on particle size. All of the pulse

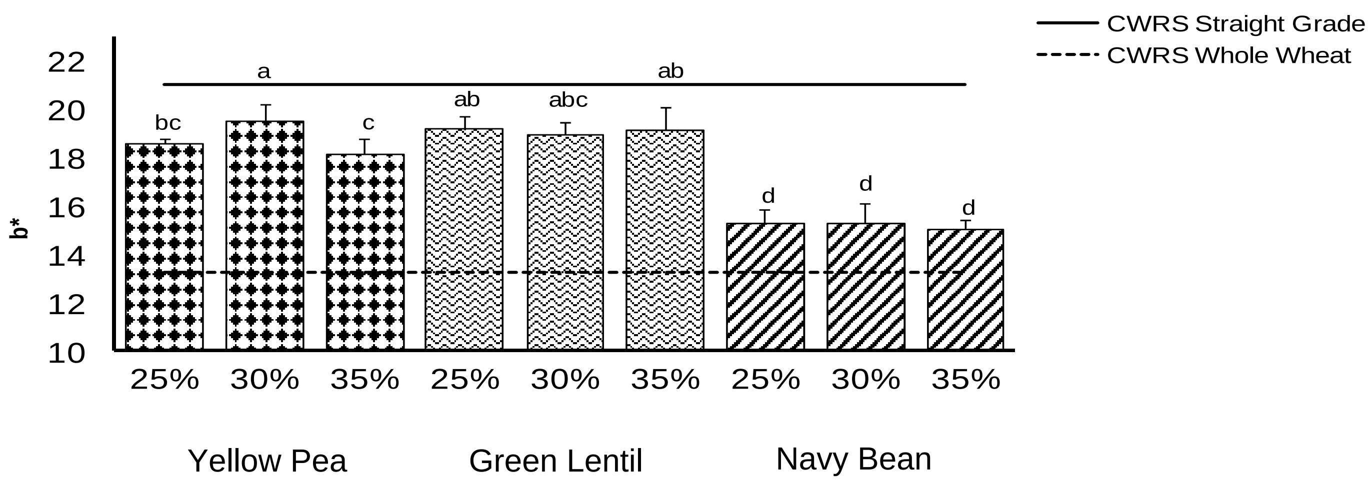

Figure 11a: Interaction Effect between Pulse Type and Blend Level for b* Values of Dried White Salted Noodles made with Selected Pulse Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

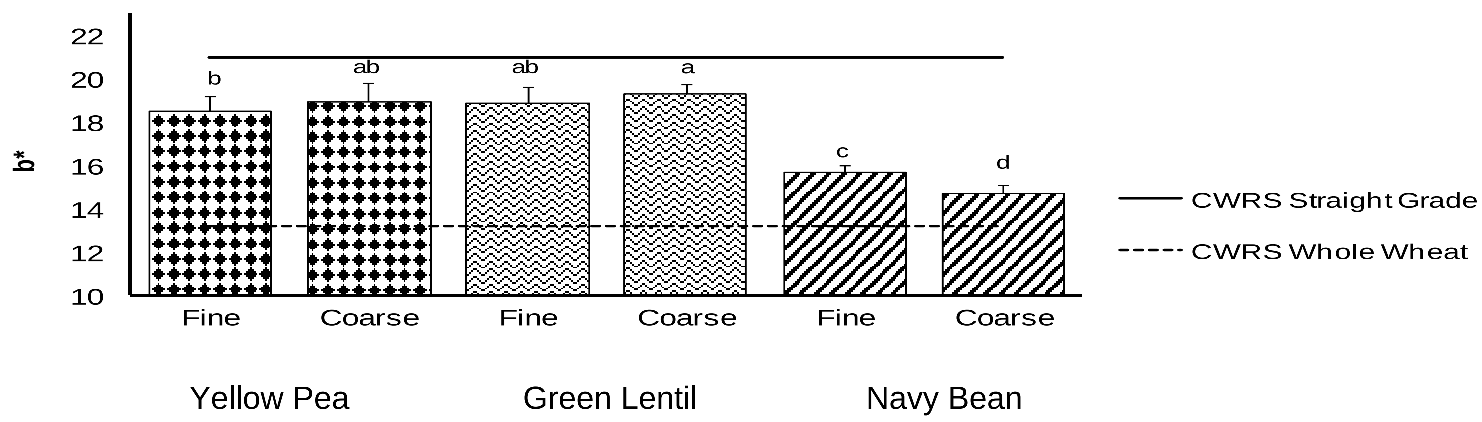

Figure 11b: Interaction Effect between Pulse Type and Particle Size for b* Values of Dried White Salted Noodles made with Selected Pulse Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

noodles had lower b* values than the CWRS straight grade control and were higher than the CWRS whole wheat control.

4.3.6. Cooked Noodle Colour

Colour analysis was also performed on the cooked noodles. The summary of ANOVA results for all of the colour values of the cooked noodles can be seen in Tables 45-47. In general, the cooked noodles had lower L*, a*, and b* values compared to the dried noodles. Petitot et al (2010) reported similar results when comparing a* and b* values of cooked and dried pasta; however, they observed an increase in L* values indicating the pastas that contained pulse flours became brighter, however, these increases were not significant.

Table 45: Summary of Analysis of Variance Results for L* Values for Cooked White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	1914.0797	16853.14	<0.0001
Blend Level (BL)	2	6.8656	60.4500	<0.0001
Particle Size (PS)	1	0.1701	2.9961	0.0892
PT * BL	4	18.2047	80.1445	<0.0001
PT * PS	2	1.0771	9.4836	0.0003
BL * PS	2	0.5006	4.4076	0.0169
PT * BL * PS	4	0.9717	4.2777	0.0044

Table 46: Summary of Analysis of Variance Results for a* Values for Cooked White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	69.786769	4906.243	<0.0001
Blend Level (BL)	2	0.525119	36.9177	<0.0001
Particle Size (PS)	1	0.040139	5.6438	0.0211
PT * BL	4	0.911347	32.0354	<0.0001
PT * PS	2	0.041203	2.8967	0.0638
BL * PS	2	0.020536	1.4438	0.2450
PT * BL * PS	4	0.060897	2.1406	0.0883

Table 47: Summary of Analysis of Variance Results for b* Values for Cooked White Salted Noodles made with Pulse Flours

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	46.926669	140.4515	<0.0001
Blend Level (BL)	2	12.401419	37.1174	<0.0001
Particle Size (PS)	1	0.200556	1.2005	0.2781
PT * BL	4	3.304756	4.9456	0.0018
PT * PS	2	0.209786	0.6279	0.5376
BL * PS	2	1.151053	3.4451	0.0391
PT * BL * PS	4	2.149145	3.2162	0.0193

The results from the L* values of the cooked noodles revealed a three way interaction between pulse type, blend level and particle size. The mean values for the L* values of the cooked noodles can be seen in Figure 12. The cooked noodles followed the same trend observed with the dried pulse noodles with the navy bean noodles being the lightest and the green lentil noodles the darkest. All of the noodles became darker when cooked. Again, both the yellow pea and the navy bean noodles were brighter than the 100% CWRS straight grade noodles.

There were no significant differences ($p \geq 0.05$) among the yellow pea noodles based on blend level or particle size. The green lentil noodles became darker as the amount of green lentil flour increased, which was observed for the dry noodles as well. The only significant particle size effect was for the 35% coarse green lentil flour which was significantly higher than the corresponding fine flour.

Both the yellow pea and navy bean noodles had higher L* values than the 100% CWRS straight grade control. Among all the noodles, the navy bean noodles made with 35% coarse flour were the brightest and were significantly different ($p \geq 0.05$) than the 30% coarse and 25% fine navy bean noodles as well as all the green lentil and yellow pea noodles. The whole wheat noodles were the darkest of all noodle samples.

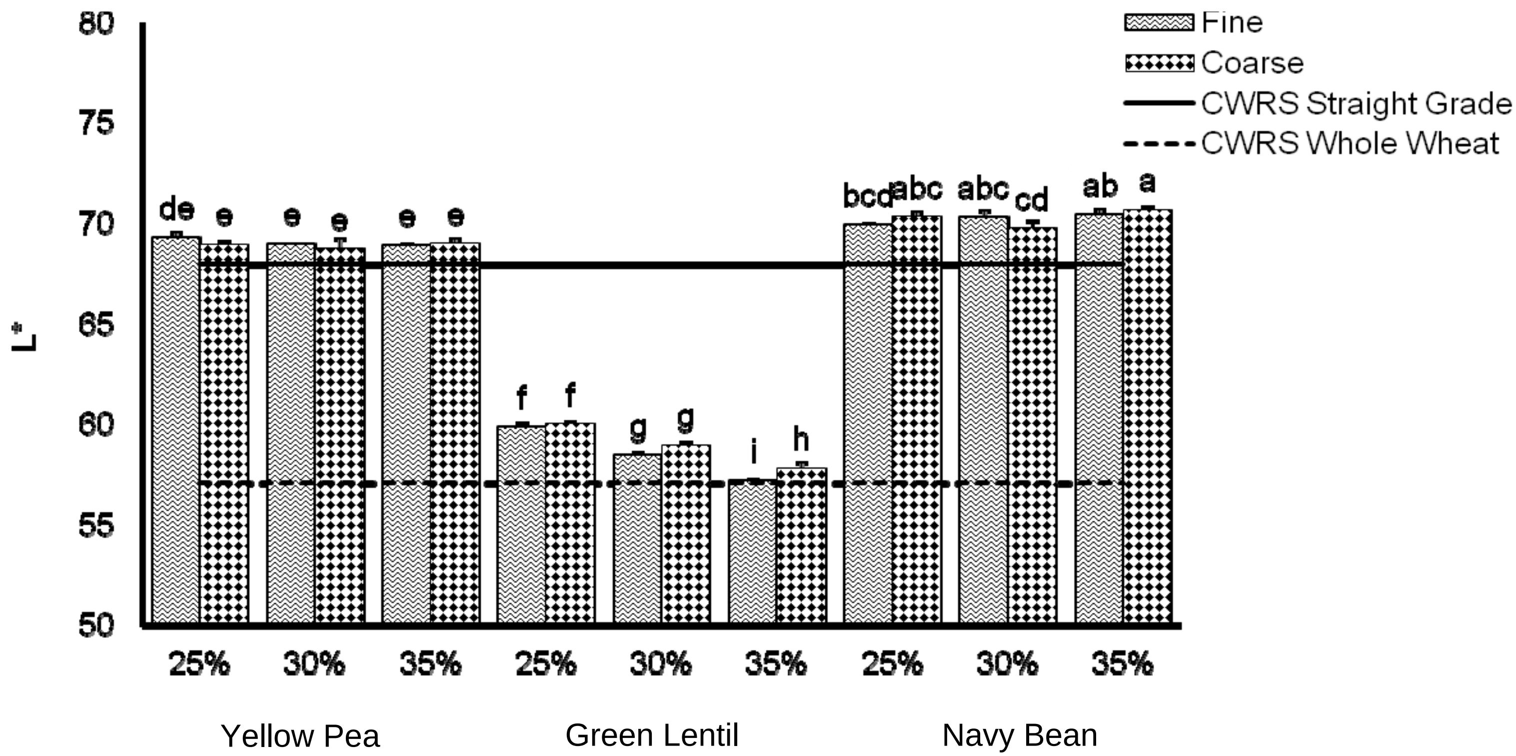

Figure 12: Mean L* Values for Cooked White Salted Noodles made with Pulse Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

A two way interaction was observed for a* values of the cooked pulse noodles between pulse type and blend level (Figure 13). Mean a* values of the cooked noodles for all treatments can be seen in Appendix M. The 35% yellow pea noodles were the only cooked noodles that were greener than the 100% CWRS straight grade noodles while the CWRS whole wheat sample had the highest a* values of all the noodles. Compared to the dried noodles, both the yellow pea and the navy bean noodles decreased in a* value indicating an increase in greenness when cooked. For the cooked navy bean noodles, there were no significant differences ($p \geq 0.05$) between blend levels.

The green lentil noodles were surprisingly, the least green, or had the highest a* values of all the three types of pulse noodles that were cooked. An increase in redness, or decrease in greenness was observed as the amount of green lentil flour increased. This is the opposite of what was observed in the dried noodles where the noodles appeared greener as the amount of green lentil flour increased. Despite this difference, the mean a* values of the dried and cooked green lentil noodles did not seem to be affected by cooking as their a* values did not change much between the cooked and the dried noodles. Analysis was not done on cooking losses for any of the noodles, however, it was observed that after the noodles were cooked, the cooking water remained quite clear indicating that the cooking losses were likely low.

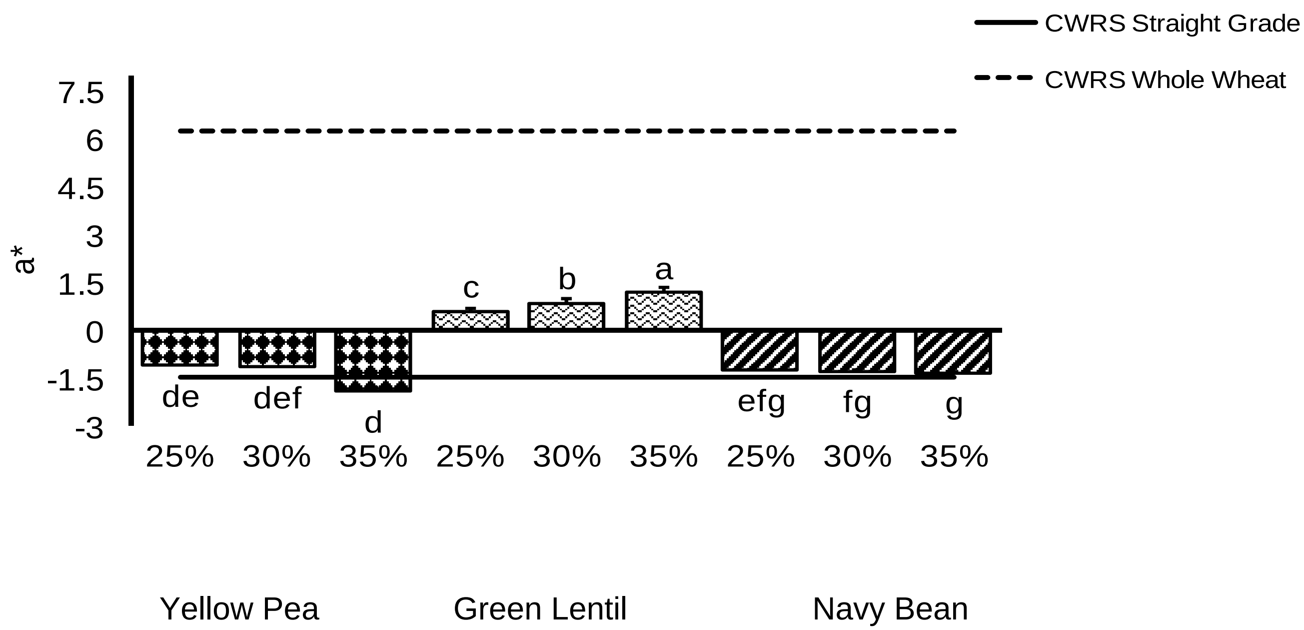

Figure 13: Interaction Effect between Pulse Type and Particle Size for a* Values for Cooked White Salted Noodles made with Pulse Flours. Bars with the same letter are not significantly different ($p \geq 0.05$)

A three way interaction between pulse type, blend level and particle size was observed for the b* values of the cooked pulse noodles (Figure 14). As was seen with the dried noodles there were no significant differences ($p \geq 0.05$) observed for the green lentil flours regardless of pulse type, blend level or particle size. For both the navy bean and green lentil noodles, the b* values increased as the blend level increased.

The only significant difference ($p \geq 0.05$) observed for the yellow pea noodles for b* values was between the noodles made with 25 and 35% fine flours. The 35% fine yellow pea noodles were significantly more yellow than the 25% fine noodles. A similar observation was observed with the navy bean noodles with significant differences ($p \geq 0.05$) between the 25 and 35% noodles regardless of particle size.

The colour of dried white salted noodles is an important quality parameter that affects a consumer's choice when deciding to purchase noodles. A white or creamy white colour is preferred (Fu, 2008). Adding pulse flours has been shown to have an effect on the colour of both dried and cooked noodles. Although using pulses that have distinct colours such as green lentils may result in a less desirable noodle colour for consumers, pulses that have more neutral colours such as navy beans or yellow peas may be more suitable it attempting to replicate noodles made from traditional wheat flour.

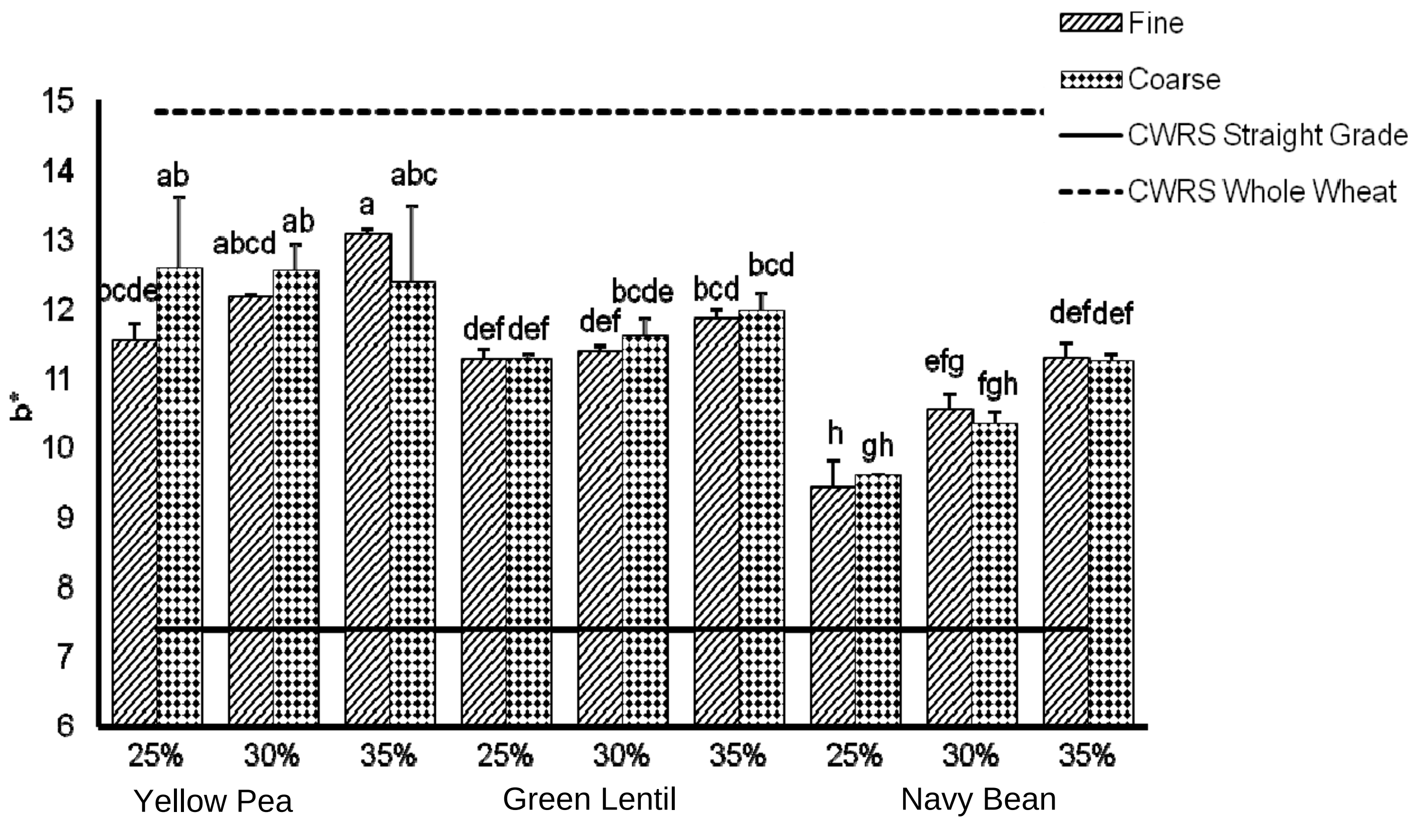

Figure 14: Mean b* Values of Cooked White Salted Noodles made with Selected Pulse Flours. Bars with the same letter are not significantly different ($p \leq 0.05$)

4.3.7. Anti-Nutritional Factors

Only the noodles made with 35% pulse blended noodles were evaluated for anti-nutritional factors. The summaries of ANOVA for total phenolics, trypsin inhibitors and phytic acid can be seen in Tables 48-50.

Table 48: Summary of Analysis of Variance Results for Total Phenolics of 35% Pulse Noodles

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	21.045520	1280.323	<0.0001
Particle Size (PS)	1	0.019078	2.3213	0.1450
PT * PS	2	0.028118	1.7106	0.2089

Table 49: Summary of Analysis of Variance Results for Trypsin Inhibitors of 35% Pulse Noodles

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	49.095350	66.0550	<0.0001
Particle Size (PS)	1	0.025208	0.0678	0.8032
PT * PS	2	0.193317	0.2601	0.7792

Table 50: Summary of Analysis of Variance Results for Phytic Acid of 35% Pulse Noodles

Source	DF	Sum of Squares	F ratio	Prob > F
Pulse Type (PT)	2	19.178600	12.8573	0.0068
Particle Size (PS)	1	0.054675	0.0733	0.7957
PT * PS	2	3.429600	2.2992	0.1814

The mean values of total phenolics, trypsin inhibitors and phytic acid on the 35% dried pulse noodles can be seen in Table 51. Pulse type was the only factor that had a significant effect on any of the three anti-nutritional factors that were analyzed ($p \leq 0.05$). The noodles followed the same trends that were observed for the flours. Trypsin inhibitors and phytic acid where highest in the navy bean noodles while total phenolics was highest in the green lentil noodles. The levels that were present in the 100% pulse flours were much higher than in the noodles, which is to be expected as the pulse flours only made up 35% of the total noodle flour content. Although anti-nutritional factors have been shown to have negative physiological effects, research exists that they offer positive physiological benefits as well (Carbonaro, 2011). For these reasons, more research is needed to determine beneficial levels of anti-nutritional factors (Carbonaro, 2011). Examining the anti-nutritional factors of the cooked noodles was outside the scope of this study and therefore needs to be further examined as cooking will likely reduce the amounts of anti-nutritional factors that are present in the noodles.

Table 51: Mean[1] Values of Anti-Nutritional Factors in Dried White Salted Noodles made with 100% Wheat and 35% Pulse Flours

	Total Phenolics[4]	Trypsin Inhibitors[4]	Phytic Acid[4]
100% CWRS Straight Grade[2]	0.36 ± 0.10	0.81 ± 0.03	1.08 ± 0.29
100% CWRS Whole Wheat[3]	0.86 ± 0.81	0.81 ± 0.06	11.28 ± 0.22
35% Yellow Pea	0.48 ± 0.04[b]	2.68 ± 0.34[b]	3.28 ± 1.40[b]
35% Green Lentil	2.44 ± 0.15[a]	2.45 ± 0.11[b]	4.16 ± 0.78[b]
35% Navy Bean	0.42 ± 0.05[b]	6.85 ± 0.83[a]	6.29 ± 0.30[a]

[1] Means are all measurements ± SD of both particle sizes.

[23] CWRS straight grade and whole wheat noodles were not included in the statistical analysis as they were available at only one particle size and are included for comparison purposes.

[4] Means within the same column followed by the same letter are not statistically different ($p \leq 0.05$)

4.4. Sensory Analysis

4.4.1. Smoothness

Panelists were asked to evaluate noodles based on smoothness, which required the panelists to take the noodles into their mouth and run their tongue along the surface of the noodle. The mean values for smoothness of the pulse noodles are presented in Figure 15a and 15b while the summary of ANOVA can be seen in Table 52.

Table 52: Summary of Analysis of Variance Results for Sensory Smoothness

Source	DF	F ratio	Prob > F
Pulse Type (PT)	2	3.2511	0.0653
Blend Level (BL)	2	13.0539	0.0004
Particle Size (PS)	1	7.3751	0.0264
PT * BL	4	1.5150	0.2212
PT * PS	2	0.4956	0.6183
BL * PS	2	0.1357	0.8741
PT * BL * PS	4	2.3768	0.0721

There were no interaction effects observed between any of the main effects, however, blend level and particle size were both significant ($p \leq 0.05$). Mean scores for smoothness for all treatments can be seen in Appendix N. Panelists scored the noodles made with the pulse flours as being rougher than the CWRS straight grade wheat flour noodles. This was due to the presence of the wheat bran in the noodles. Roughness scores increased as pulse blend levels increased (Figure 15a) and were significantly different ($p \geq 0.05$) for each blend level. Panelists found that the pulse

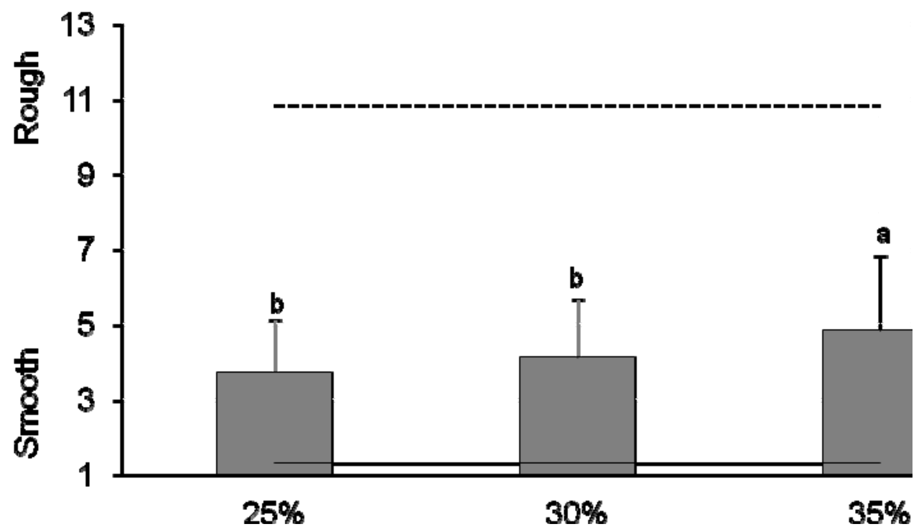

Figure 15a: Mean Sensory Scores for Perceived Smoothness by Blend Level. Bars with the same letter are not significantly different ($p \leq 0.05$).

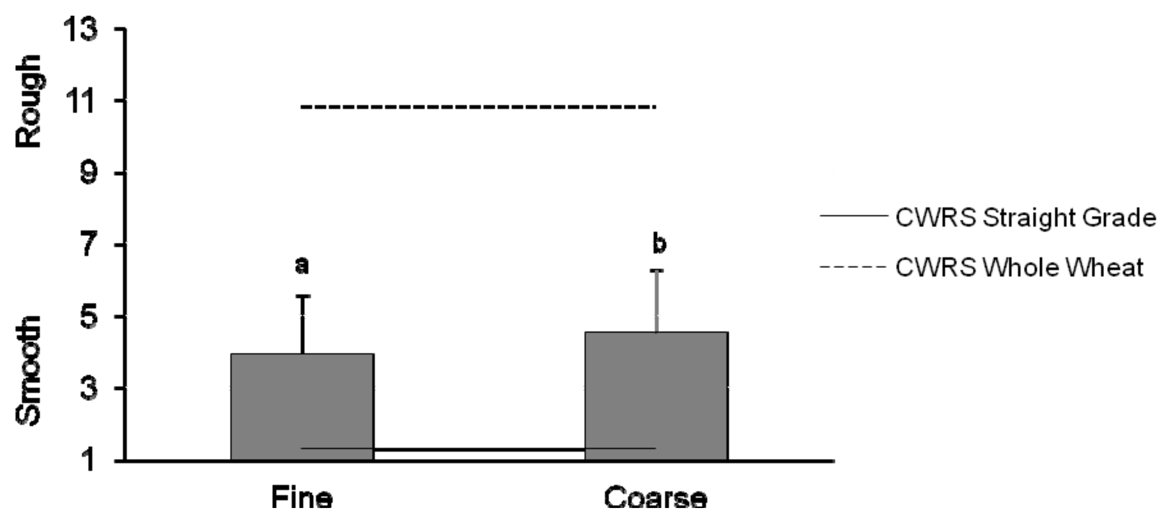

Figure 15b: Mean Sensory Scores for Perceived Smoothness by Particle Size. Bars with the same letter are not significantly different ($p \leq 0.05$)

noodles made with the coarse flours were less smooth than those made with fine flours (Figure 15b).

Both the coarse and the fine pulse flours had larger particles than the CWRS straight grade flour which would explain why the panelists observed differences in smoothness. Despite particle size not having a significant effect on some quality parameters measured instrumentally, the results from this sensory panel are an indication that the particle size of the flours is an important characteristic to consider for consumer acceptability and that using pulses that have a finer particle size maybe more suitable in noodle applications.

4.4.2. Elasticity

Elasticity, which is sometimes referred to as springiness, is the ability of noodles to return to their original shape once being bitten through by the molars. Two way interactions were observed between pulse type and blend level and pulse type and particle size and can be seen in Figures 16a and b. The summary of ANOVA can be seen in Table 53.

Table 53: Summary of Analysis of Variance Results for Sensory Elasticity

Source	DF	F ratio	Prob > F
Pulse Type (PT)	2	4.7912	0.0234
Blend Level (BL)	2	13.4666	0.0004
Particle Size (PS)	1	6.9792	0.0296
PT * BL	4	4.7890	0.0038
PT * PS	2	3.8317	0.0437
BL * PS	2	1.7501	0.2054
PT * BL * PS	4	0.9736	0.4356

Unlike what was seen with smoothness where only main effects were observed, interaction effects occurred in the evaluation of elasticity. There were no significant differences ($p \leq 0.05$) observed among the yellow pea flour noodles regardless of blend level (Figure 16a). Mean scores for elasticity for all treatments can be seen in Appendix O. Both the green lentil and navy bean noodles decreased in elasticity as the blend level increased and differences were significant between the 25 and 35% noodles. The only significant difference ($p \leq 0.05$) due to particle size (Figure 16b) was in the green lentil noodles where the noodles made with coarse flour had less elasticity compared to the noodles made with the fine flour. Although not significantly different, this same trend was observed for the navy bean noodles.

Zhao et al (2005) saw similar decreases in elasticity with the addition of green and yellow pea, lentil, and chickpea flours to spaghetti and also observed that the elasticity continued to decrease as the blend level increased. All of the pulse noodles were less elastic than the 100% CWRS straight grade wheat flour noodles but had more elasticity than the CWRS whole wheat flour noodles.

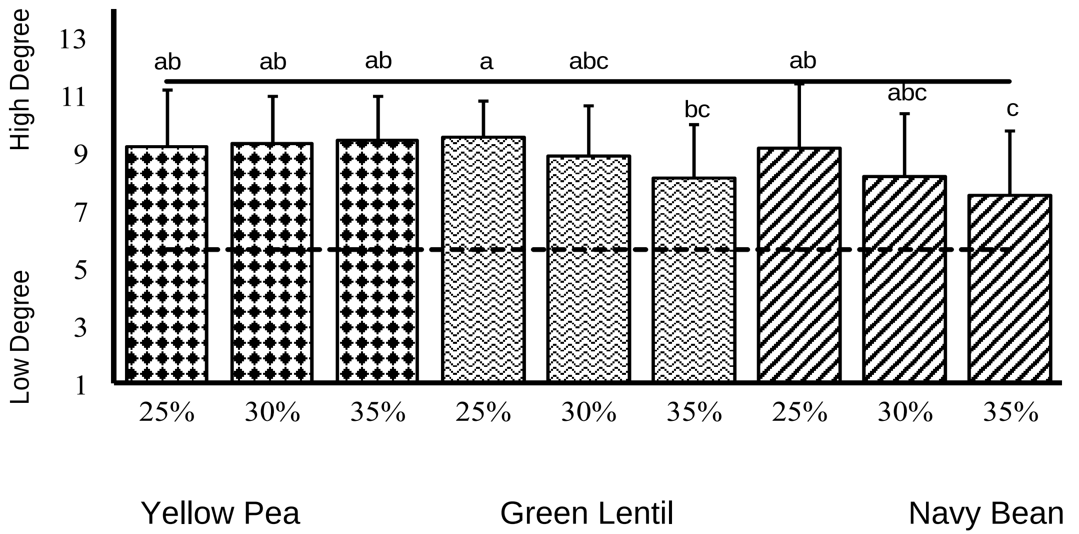

Figure 16a: Interaction Effect between Pulse type and Blend Level of Sensory Scores for Elasticity. Bars with the same letter are not significantly different ($p \leq 0.05$)

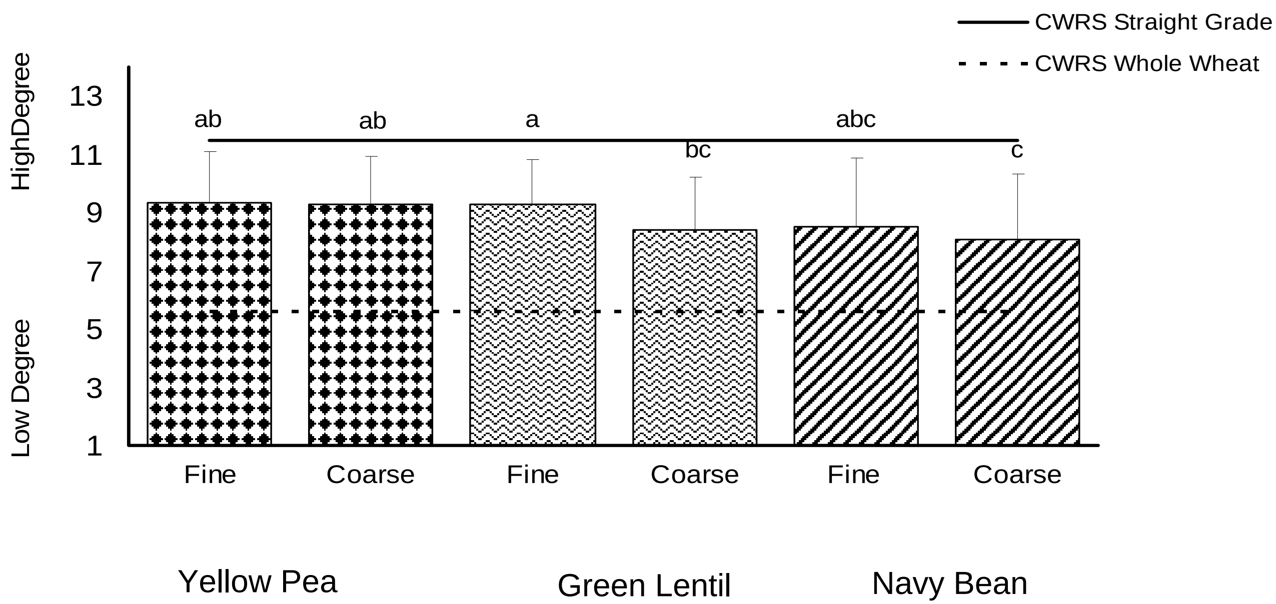

Figure 16b. Interaction Effect between Pulse Type and Particle Size of Sensory Scores for Elasticity. Bars with the same letter are not significantly different ($p \leq 0.05$)

4.4.3. Firmness

Of all the sensory parameters that were evaluated by panelists, firmness was the only one that was also measured instrumentally. Panelists were asked to rate the amount of force that was required to bite through the noodle using their molar teeth. The summary of ANOVA can be seen in Table 54.

Table 54: Summary of Analysis of Variance Results for Sensory Firmness

Source	DF	F ratio	Prob > F
Pulse Type (PT)	2	2.3086	0.1316
Blend Level (BL)	2	2.8536	0.0870
Particle Size (PS)	1	0.0560	0.8188
PT * BL	4	0.4220	0.7915
PT * PS	2	2.4197	0.1207
BL * PS	2	0.5768	0.5729
PT * BL * PS	4	0.6664	0.6200

There were no significant main effects for firmness. Mean scores for firmness for all treatments can be seen in Appendix P. The firmness scores for all pulse noodles had a mean of 10.56 and was similar to the score given to the 100% CWRS straight grade noodles, which had a mean of 10.20, indicating that the addition of pulse flours did not have an effect on firmness regardless of pulse type, blend level or particle size. The instrumental analysis of firmness showed an interaction between pulse type and blend level that indicated the noodles made with green lentil flour were the firmest and increased in firmness as the blend level increased. The same analysis showed that the navy bean noodles were the least firm and decreased in firmness as the blend level increased. This analysis is similar to what was reported by Zhao et al (2005), Wood (2009), Bhanaessy and Khan (1986) and Pettitot et al (2010) who all reported differences in firmness with the addition of pulse flours to various pasta products.

The increased firmness was believed to be due to the increase in protein content and lower water uptake of the pastas as reported by Petitot et al (2010). Despite these results, Sabanis et al (2006) observed a decrease in firmness in lasagna noodles with the addition of chickpea flour.

The firmness of noodles is a critical textural quality in determining consumer acceptability.   Park et al (2003) reported that when wheat with a high protein content is used, the resulting noodles are firmer than noodles made with a wheat flour with a lower protein content. Although the addition of pulse flours does increase the protein content, it dilutes the gluten, which has been attributed to noodles firmness. Ross & Crosbie (2010) reported that in addition to the flour protein concentration and composition, starch composition and interactions between starch and protein may also influence the firmness of the noodles. Further investigation into these interactions with pulse and wheat flours needs to be investigated to determine their influence on noodle firmness.

4.4.4. Cohesiveness

The final textural parameter the panelists were asked to evaluate was the cohesiveness of the noodles. Panelists were asked to chew a noodle strand to the point of swallowing and evaluate the breakdown of the noodle in terms of it forming a mass or breaking into distinct pieces in the mouth. The summary of ANOVA can be seen in Table 55. Mean scores for cohesiveness for all treatments can be seen in Appendix Q.

Table 55: Summary of Analysis of Variance Results for Sensory Cohesiveness

Source	DF	F ratio	Prob > F
Pulse Type (PT)	2	2.4854	0.1148
Blend Level (BL)	2	47.0301	<0.0001
Particle Size (PS)	1	29.5924	0.0006
PT * BL	4	1.2016	0.3292
PT * PS	2	2.3591	0.1265
BL * PS	2	1.0699	0.3663
PT * BL * PS	4	2.4010	0.0704

There were no interactions among the main effects, however, both blend level and particle size were significant. For all of three pulse types, the level of cohesiveness increased as the blend level increased and was significantly different for each blend level (Figure 17a). Panelists determined that the pulse noodles had a higher degree of cohesiveness compared to the CWRS straight grade noodles. Particle size was also significant with noodles made with coarse flour having a higher degree of cohesiveness in comparison to noodles made with the fine pulse flours (Figure 17b). All of the pulse noodles, regardless of blend level or particle size were less cohesive than the CWRS whole wheat noodles.

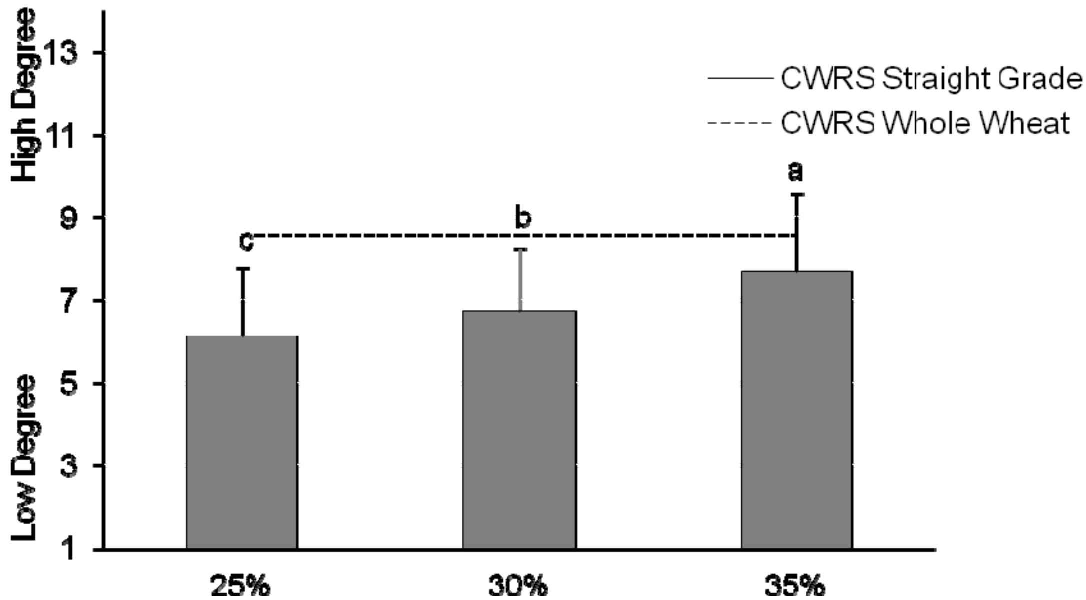

Figure 17a: Mean Sensory Scores for Cohesiveness by Blend Level. Bars with the same letter are not significantly different ($p \leq 0.05$)

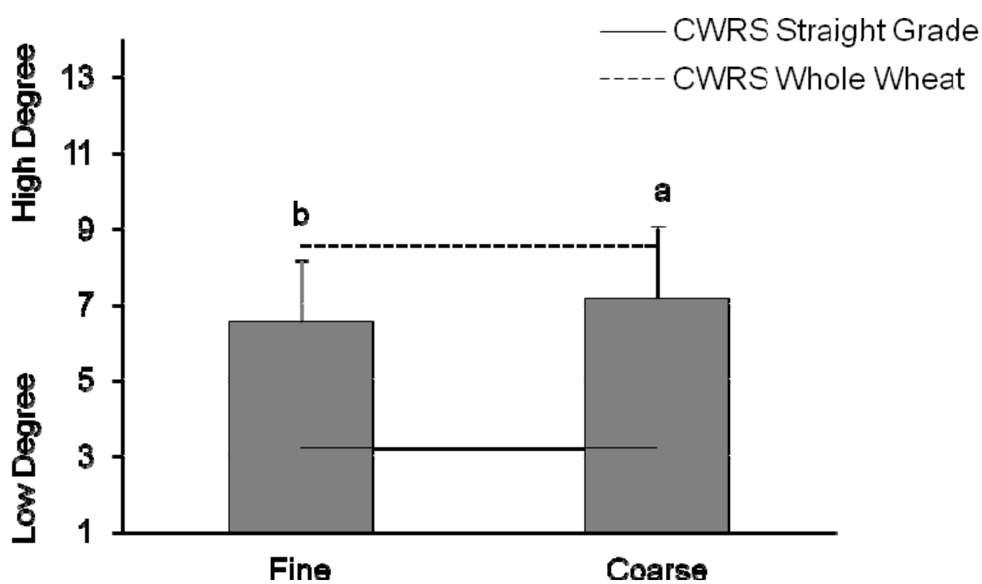

Figure 17b: Mean Sensory Scores for Cohesiveness by Particle Size. Bars with the same letter are not significantly different ($p \leq 0.05$)

4.4.5. Flavour Intensity

Panelists evaluated the noodles for flavour intensity and were asked to rate the flavour intensity of the noodles while chewing. The summary of ANOVA can be seen in Table 56 while the mean values are presented in Figure 19.

Table 56: Summary of Analysis of Variance of Sensory Flavour Intensity

Source	DF	F ratio	Prob > F
Pulse Type (PT)	2	4.8543	0.0225
Blend Level (BL)	2	6.2821	0.0097
Particle Size (PS)	1	9.8144	0.0140
PT * BL	4	2.1905	0.0924
PT * PS	2	0.0288	0.9716
BL * PS	2	0.4208	0.6636
PT * BL * PS	4	3.7964	0.0123

A three way interaction was observed between pulse type, blend level and particle size (Table 56). For both green lentil and navy bean flour noodles, flavour intensity increased as the blend levels increased. The noodles made with the coarse flour appeared to have a more intense flavour compared to the noodles made with the fine flour at the same blend level except for the noodles made with 25% yellow pea flour. Yellow pea flour noodles, specifically made with 25% coarse flour, had the highest score for flavour intensity while the navy bean flour noodles had the lowest score. All of the noodles made with pulse flours had a higher flavour intensity than the CWRS straight grade wheat noodles. The CWRS whole wheat flour noodle also had a higher flavour intensity score than the CWRS straight grade wheat flour noodles.

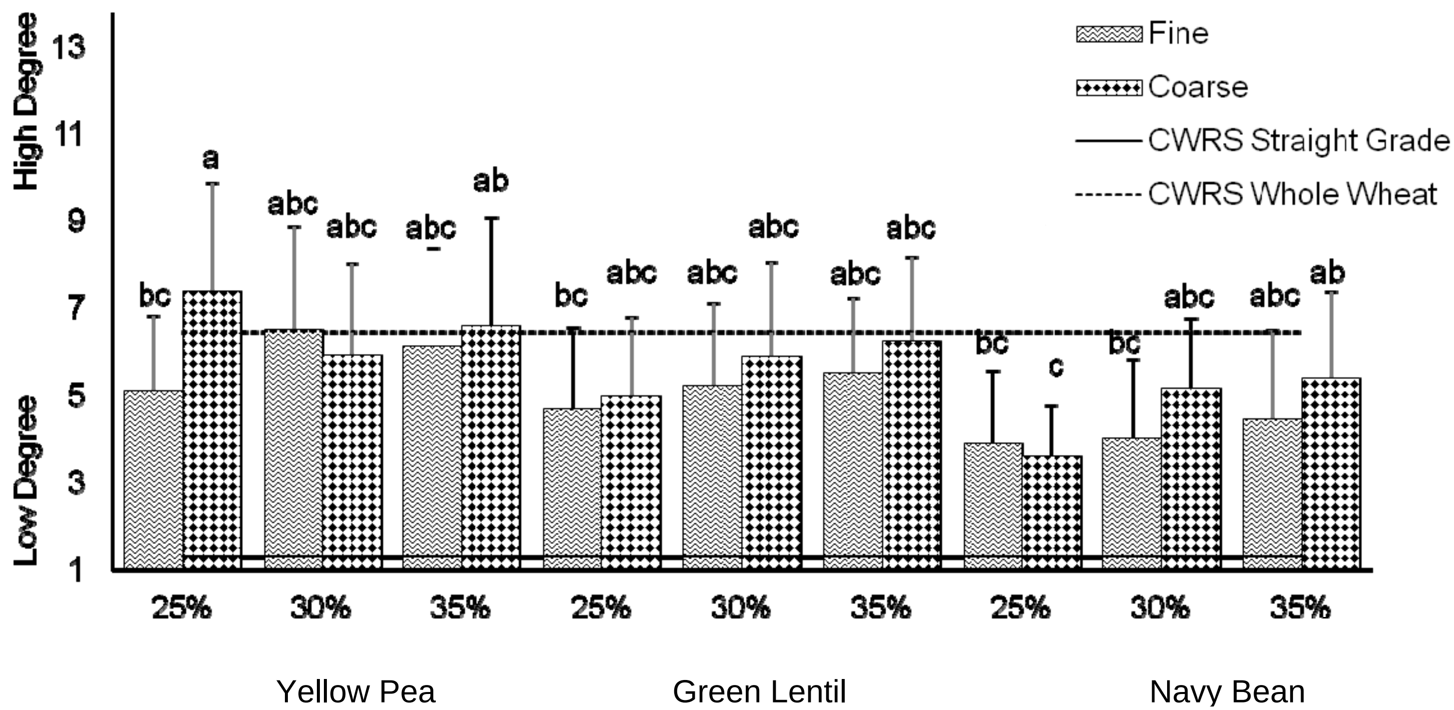

Figure 18: Mean Sensory Scores for Flavour Intensity. Bars with the same letter are not significantly different ($p \leq 0.05$)

4.4.6. Aftertaste

Pnaelists also evaluated the noodles for aftertaste which was defined as the taste left in the mouth within 10 seconds of swallowing the noodle. The summary of ANOVA table can be seen in Table 57. The mean scores of aftertaste are presented in Figure 20.

Table 57: Summary of Analysis of Variance Results of Sensory Aftertaste

Source	DF	F ratio	Prob > F
Pulse Type (PT)	2	3.0504	0.0755
Blend Level (BL)	2	5.2897	0.0172
Particle Size (PS)	1	5.8446	0.0420
PT * BL	4	3.3336	0.0217
PT * PS	2	0.5136	0.6079
BL * PS	2	0.1083	0.8980
PT * BL * PS	4	3.4806	0.0181

A three way interaction was observed between pulse type, blend level and particle size. As was seen with flavour intensity, the 25% coarse yellow pea flour noodles, had the highest aftertaste score for all the pulse noodles, however, they were not significantly different than any of the other yellow pea flour noodles. There were no significant differences among or within the green lentil and navy bean flour noodles, however, the scores for aftertaste were generally higher as the blend level increased. The only significant effect ($p \geq 0.05$) based on particle size occurred between the 25% coarse noodles. The 25% coarse yellow pea flour noodles had a significantly stronger aftertaste than both the 25% coarse and fine green lentil flour noodles as well as the 25% coarse and fine, and the fine 30 and 35% navy bean flour noodles.

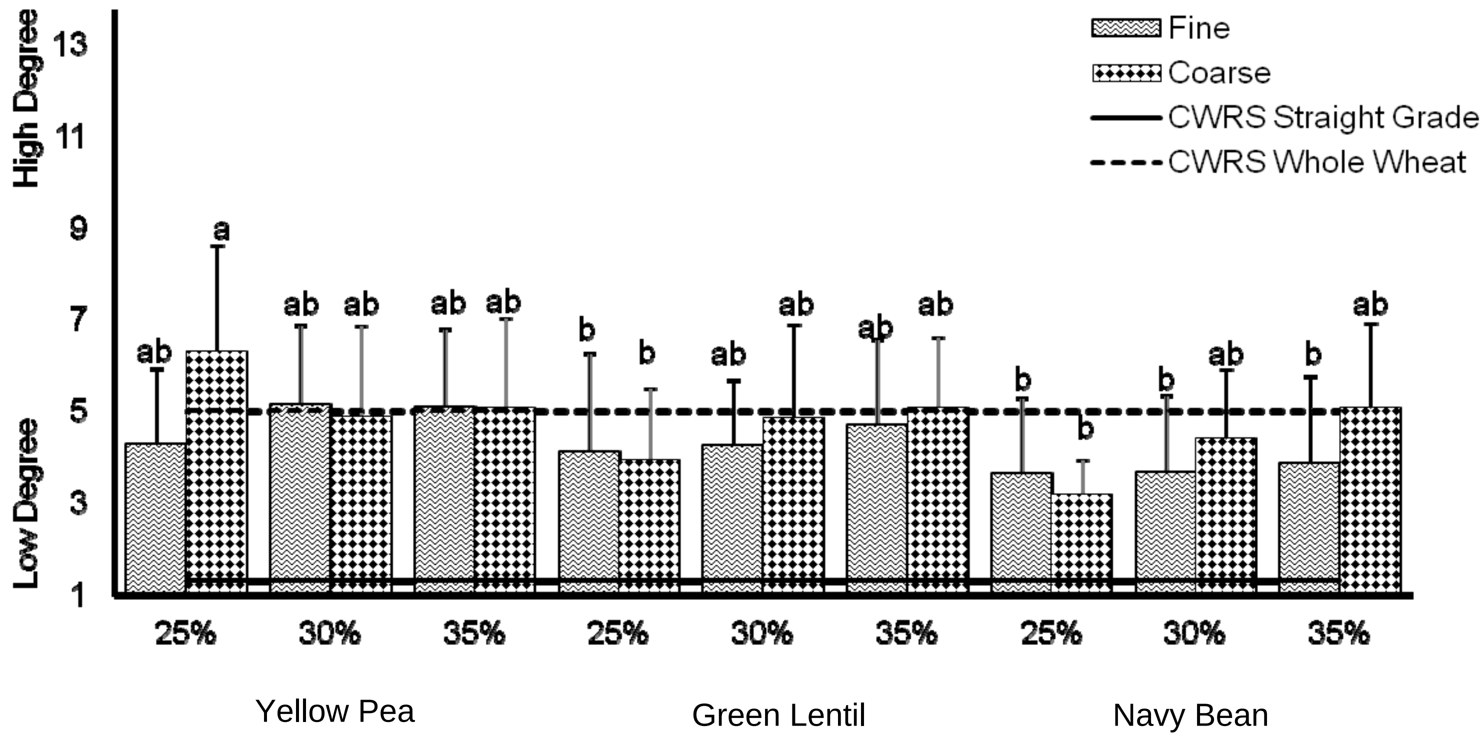

Figure 19: Mean Sensory Scores for Aftertaste. Bars with the same letter are not significantly different ($p \leq 0.05$)

There is limited research available that looks at the sensory evaluation of white salted noodles made with pulse flours. The sensory data that does exist tend to focus on pasta products and how blend levels and pulse types score with consumer acceptability. Sabanis et al (2006) found that 5% chickpea flour in lasagna was the most acceptable to panelists in terms of flavour and overall acceptability whereas Wood (2009) found that an inclusion of up to 30% chickpea flour in spaghetti could be used without compromising consumer acceptability. Preference for pulse type has also been shown in sensory panels. Zhao et al (2005) concluded that spaghetti made with lentil flours had higher flavour acceptability scores than spaghetti made with chickpea or yellow pea flours. Hung & Nithianandan (1993) reported higher consumer acceptability for noodles made with chickpea and lupin flours compared to the traditional wheat flours. This study did not include a consumer panel that would have provided an indication of preference and acceptability of the noodles made with pulse flours. The previous research done on the acceptability of noodle and pasta products formulated with various pulses stresses the need for this work to be done in the future.

The research done so far on both noodle and pasta products clearly illustrates that the type of pulse used for formulation and the level of incorporation are key factors in achieving acceptable sensory quality. This is an indication that each pulse type should be examined individually to determine acceptable blend levels and consumer preferences.

CHAPTER 5: CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 Conclusions

The overall objective of this study was to develop dried Asian white salted noodles using blends of selected pulse flours with wheat flour to create a noodle with increased nutritional benefits without significantly affecting the colour and texture of the end products. In order to determine the suitability of the flours as ingredients, analysis was done on the 100% wheat flours, the 100% pulse flours, and all of the wheat and pulse flour blends. A summary of main effects can be seen in Appendices R and S.

Based on the analysis of the flours and flour blends used in this study it can be concluded that the pulse flours could be successfully incorporated into white salted noodle formulations. Pulse type, blend level and particle size were all factors that played a role in the functionality and composition of the flours used in this study and therefore, ultimately affected the end noodle products. The pulse flours had higher protein and dietary fibre contents and improved the nutritional value of the noodles made with pulse flours. The pasting properties of the blended flours and increased water absorption capacity were an indication that certain parameters associated with noodle quality, such as firmness and eating quality would be affected.

Pulse type appeared to be the most influential factor in determining the suitability of the pulse flours in the noodle applications as it was a significant main effect or involved in an interaction for most of the parameters. Specifically, pulse type affected pasting properties, colour, starch damage, and compositional properties of the flours and therefore, it can be concluded that specific pulse types may be more suitable when trying to achieve specific targets. In this study, navy bean flours produced a noodle that was comparable in lightness to the control noodles and therefore may be more suitable than the green lentil flour which produced a darker noodle.

Also important was the effect of blend level. As was seen with pulse type, blend level had an effect on compositional properties, pasting properties and colour. Increasing the amount of pulse flours used in the blends, resulted in a flour with a higher protein and fibre content which was an objective of this study. Higher blend levels also intensified colour, usually making it lighter, in the case of the navy bean flour noodles, or darker as was seen in the green lentil flour noodles. Pasting properties, although generally higher than the control, tended to decrease as the blend level increased. This study illustrated that the use of different blend levels will affect certain functional or compositional characteristics and therefore, careful consideration needs to be taken to ensure that quality characteristics are not compromised.

The last factor, which was particle size had the greatest effect on colour which was attributed to the ability of the flour particles to dissolve in the slurries. Although particle size did have an effect on the pasting properties, starch damage and water absorption capacity of the 100% pulse flours, these effects were not significant in the blended flours.

Pulse type, blend level and particle size all had a significant effect on pulse and wheat flour blends properties. However, based on the analysis that was performed, there was nothing to indicate that the pulse flours could not be successfully incorporated into dried white salted noodles. The differences that were seen in the flour blends lead to the hypothesis that certain end-product quality parameters, such as colour and texture, would be significantly affected by one or more of these factors.

An objective of this study was to determine how the addition of pulse flours affected the processing of the noodles on the pilot scale equipment. The only change that had to be made to processing was the amount of water that had to be added to the noodle dough formulation. Using the same amount of water that was used in CWRS straight grade noodles created sticky dough that decreased machinability. Difficulties that occur during processing are problematic in commercial industries as they require manpower to fix as well as down time of the equipment that results in lost productivity. This work illustrated that by decreasing the amount of water used in the dough formulation according to blend level, pulse noodles could be processed without complications.

With the minor adjustments made in the noodle formulation during processing, dried white salted noodles were successfully produced using wheat and pulse flour blends at blend levels of 25, 30 and 35%. A summary of main effects and interactions for pulse type, blend level and particle size can be seen in Appendix T.

As was seen with the analysis done on the wheat and pulse flour blends, pulse type, blend level and particle size all had an effect on most of the quality parameters that the noodles were analyzed for. The incorporation of these pulse flours improved the nutritional profile of the noodles by increasing both the protein and total dietary fibre content. There was an effect on cooking times of the noodles that increased or decreased depending on the pulse type, which was attributed to compositional differences among the pulse types and from the CWRS wheat flour.

Differences in colour were observed, however, the degree of change depended on the type and amount of pulse flour that was used. Green lentil flour appeared to have the greatest effect in terms of darkening the noodles whereas navy bean flours appeared to increase the lightness of the noodles, which, in most cases, is a highly desirable quality characteristic. The differences in colour based on pulse type can be attributed to the differences in phenolic compounds. Green lentil flour had the highest phenolic content, while both navy bean and yellow pea flours had phenolic contents closer to the CWRS straight grade flour.

According to the instrumental firmness evaluation, noodles made with pulse flours were generally firmer than the CWRS straight grade wheat flour noodles. Based on the literature, this was expected. The literature also suggested that during sensory analysis, panelists reported an increase in firmness, in agreement with the instrumental analysis. In this study, the trained sensory panel did not detect any differences in firmness of the noodles nor were the pulse noodles different than the wheat noodles, regardless of the pulse type, the blend level or the particle size. This is an indication that yellow pea, green lentil and navy bean flours can be successfully added into dried white salted noodles at levels of up to 35% without having a negative effect on firmness.

Although the sensory panel did not detect differences in noodle firmness, significant differences were found in the smoothness, elasticity, cohesiveness, flavour intensity and aftertaste. Differences in smoothness were attributed to both the blend level and particle size of the pulse flours. From these results it can be concluded that using a flour with a fine particle size is critical in noodle applications as differences in particle size will affect the perceived smoothness of the cooked noodle.

Elasticity and cohesiveness of noodles were also affected by the addition of pulse flours. While the addition of pulse flours decreased the elasticity of the noodles compared to the noodles made CWRS straight grade flour, cohesiveness increased. For both of these textural characteristics, the blend level appeared to have the greatest effect followed by particle size. Of the three factors, pulse type only appeared to have an effect on the elasticity of the noodles, and not the cohesiveness.

Lastly, the flavour intensity and aftertaste scores were an indication that when incorporating fine and coarse pulse flours at 25, 30 and 35%, flavour characteristics were affected. It can be concluded that the addition of pulse flours will affect the flavour of the noodles, and as this level of addition increases, a stronger flavour and aftertaste will occur.

The addition of pulse flours to dried Asian white salted noodles did have an effect on certain textural and flavour characteristics, which were detected by a trained sensory panel. In order to determine whether these characteristics are detrimental to the end noodle quality a consumer sensory panel would need to be conducted which would determine consumer acceptability.

This study clearly illustrated that pulse flours could be successfully incorporated into dried white salted noodles at blend levels of 25, 30 and 35%. Based on the quality parameters, which are used to evaluate noodles, pulse flours of a finer particle size are more suitable for noodle applications. Careful consideration needs to be given to both pulse type and blend level to ensure that there are nutritional advantages for consumers that do not result in an end product of poor quality. Of the three pulse flours used in this study, the noodles made with the navy bean flour had the lightest colour, scoring higher than noodles made with CWRS straight grade flour. They also had the lowest scores for flavour intensity and aftertaste of the three pulse flours used. Based on these results, navy bean flour, with a fine particle size was successfully incorporated and is suitable for dried white salted noodles when incorporated at levels between 25 and 35%.

5.2. Limitations and Recommendations for Future Research

One of the limitations of this research was that the bran particles in the whole wheat flour were not milled to a similar particle size as the other flours. The CWRS whole wheat sample was being used so that the whole pulse flours could be compared to a whole wheat flour. When producing the whole wheat flour, the bran that was incorporated back into the flour after milling, was milled using a Jacobson Hammer mill. This resulted in bran particles that had a considerably larger particle size than the flour. The large differences in particle size resulted in problems in processing, during quality evaluation and in the sensory analysis. In future studies, it would be ideal to include a whole wheat sample for comparison purposes that was of similar particle size as the other flours.

Although the processing method used for producing the pulse noodles was successful, the water addition was determined by handfeel. There is current research that looks at the optimization of water addition in noodles made with 100% wheat flour by using a mixograph to mix the dough and then sieving the dough crumbs to determine an adjusted absorption level (Hatcher et al, 2002)). Future research looking at the optimization of water absorption in noodle dough that have been supplemented with pulse flours would be beneficial as the use of different pulse types would have different effects on noodle dough based on different compositional and physical characteristics. Therefore, a more objective optimization of water absorption would lead to few processing problems.

Another limitation of this study was how the noodles were served in the sensory panel. Typically dried Asian white salted noodles would be served hot, in a flavoured broth. In this study, the noodles were served in cold water. The rational behind serving the noodles in cold water was first to stop the cooking process so that they noodles could be served to the participants as close to the optimum cooking time as possible. In addition to halting the cooking process, it was felt that serving the noodles in a hot broth may affect the panelists' evaluation of flavour intensity and aftertaste.

A necessary next step in future research is to evaluate the pulse noodles using a consumer sensory panel and serving the noodles in the manner that they would most likely be consumed. For dried white salted noodles, this would likely be in a hot broth or soup. Evaluating the noodles as they are normally consumed would be the most accurate indicator of consumer acceptance.

In addition to a consumer sensory panel, the shelf life and product stability is another future research recommendation that needs to be addressed. With the addition of a pulse flour, it is necessary to see if the product is more prone to rancidity or spoilage. The noodles may also be more prone to breaking or shattering after production, since the composition has changed. These issues are not only a concern for consumer acceptability, there is also a food safety issue that needs to be addressed.

Lastly, the anti-nutritional factors that are present in pulses were evaluated in this study. It is known that anti-nutritional factors such as trypsin inhibitors, phenolic compounds and phytic acid can have adverse health effects. Nevertheless, there is recent evidence that suggests they also have the potential, in certain amounts, to offer positive health benefits. More research is needed to determine the desirable levels of these compounds and determine if dried white salted noodles may be offering consumers added health benefits. Additionally, only the dried noodles were analyzed for anti-nutritional factors. Further research should be conducted to determine the levels present in the noodles after cooking, as this process will likely reduce the amount of anti-nutritional factors present in the noodles when ready for consumption.

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Appendix A
Noodle Processing Journal

P – Whole Yellow Pea
GL – Whole Green Lentil
NB- Whole Navy Bean
St Gd – Straight Grade
WW – Whole Wheat

25 – 25% Pulse Flour
30 – 30% Pulse Flour
35 – 35% Pulse Flour

F – Fine
C – Coarse

Sample	Added Moisture (%)	Dough Crumbs	Dough Sheet	Comments
P35F	30	Way too wet		Stuck on first pass.
P35F	28	Still too wet		Stuck on first pass (went up into noodle machine)
P35F	25	Good Size Strong smelling		
P25F	27			Strong odours
P30C	26			Strong odours
P30F	26			
St Gd Control	32	Slightly wet Good crumb size	9	Dough felt wet during processing
P25C	27	Slightly wet Small to good		Very strong smells
P35C	25	Slightly wet Good size Smelly		

GL35C	27	Very, very wet. Large Strong odours		Got stuck in the third pass. Able to save dough but not practical
GL35C	25	Good handfeel Good size Had good moisture	4 - rough, fish scale	Extremely strong odour
GL30C	26	Good handfeel Good crumb size Good moisture	6	
GL35F	25	Wet Very good size crumb	6- rough, poor hydration	
GL25F	27	Wet Very good size	6- rough, poor hydration	
WW Control	25	Flour like		After mixing, the crumbs were like flour and didn't try to sheet
WW Control	30	Still too dry		Didn't sheet
WW Control	32	Good Size Bit wet Felt hot	2 – extremely rough	Hung low on the drying rods. Very weak dough
GL30F	26	Slightly wet Slightly large	6 – hydrated and smooth. But stuck to rolls	
GL25C	27	Wet Good size	5 – not hydrated. Rough	
NB30F	26	Slightly dry Slightly small	7 – smooth and had great hydration	Does not have strong odours
NB35C	25	Sandy like dough structure too small Good moisture	7 – smooth and good hydration	
NB35F	25	Good size Good wetness	7 – smooth and good hydration	Smelled ok

NB25C	27	Wet dough Good moisture	7 – smooth and good hydration	
NB30C	26	Slightly small Slightly wet		Salt didn't dissolve very well…going to repeat
NB25C	27	Slightly wet Slightly large dough crumbs	7 – smooth and good hydration	
GL25F	27	Large dough crumbs Slightly wet	5 – dough was sloughing off at first	Very smelly
GL25C	27	Large dough crumbs Wet	5 – rough surface but good hydration	Very smelly
GL30F	26	OK size Slightly wet	6 – peeling surface	
GL30C	26	Slightly large Slightly wet	6 – rough surface	
WW Control	32	Very fine Very wet	Dough sheet had good hydration	Really brittle noodles…bran just falls off
GL35F	25	Good crumb size Slightly wet	5- Peeling	
GL35C	25	Good size crumbs Slightly wet	6 – Bit dry but surface was ok	
St Gd Control	32	Dough crumbs too large Too wet	7 – well developed but slightly sticky	Dough appeared to be weak at first
P25F	27	Slightly large Wet dough crumbs	6 – slightly dry surface	Stuck on third pass (slightly)
P30C	26	Large crumbs Wet	7 – well developed	

P35F	25	OK size Dryness was ok	6 – slightly rough surface	Piece got stuck in the roller (3rd pass)
P25C	27	Good size dough crumb Very wet	6 – slightly smoother than last sample	Slight peeling
P35C	25	Good Size Slightly wet	6 – some scaling	
P30F	26	OK size Bit wet	6 – Good surface	
NB35C	25	Sandy and small size Too dry	6 – rough and scaly	
NB30F	26	Small Slightly wet	6 - smooth	
NB25F	27	Ok Size Slightly wet	6 – smooth surface	
NB30C	27	Good to small size Slightly wet	6 - rough	
NB25C	27	Slightly small to good Slightly wet	6 – good hydration but rough	
St Gd Control	32	Slightly large Wet	8 – smooth and well developed dough	
NB25F	27	Dry and sandy dough crumb	6 – little rough	
NB30C	26	Good Size and good handfeel	6 – a bit rough	Repeat from when the salt didn't dissolve
WW Control	32	Good size Slightly wet	5 – extremely rough	

Appendix B
Recruiting of Sensory Panel
Email Invitation for Sensory Panel

Hello All,

As part of my Master's research project I will be conducting sensory panels on Asian noodles and would greatly appreciate your participation. You will be compensated for your time and participation in the study in the form of a gift card.

For those of you who have participated on sensory panels in the past, you are aware that you are required to participate in both training and test sessions. For my panel, there will be ***five 1 hour training sessions that will be held once a day from 11:00 am - noon beginning on April 11th and ending on April 15th. This will be followed by twelve 30 minute test sessions that will be held twice a day from 11:15 - 11:45 am and 3:00 - 3:30 pm beginning on April 18th ending on April 27th.*** This three week period falls on Easter weekend, therefore the test sessions will take place right up to the Thursday before Good Friday, as well as the Tuesday and Wednesday following Easter Monday. However, if we do not require all five training sessions we will begin the test sessions earlier and will conclude the study earlier.

Please let me know by APRIL 5 if you are available and willing to participate in the panel.

Thanks,
Lindsay

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Appendix # C

Letter of Consent for Participation in a Trained Sensory Panel

Research project: Sensory evaluation of cooked white salted noodles

Researchers: Lindsay Bourré. CIGI, Dr. Susan Arntfield, University of Manitoba, Dr. Linda Malcolmson, CIGI

This consent form, a copy of which will be given to you for your records and reference, provides you with information on the current research project and what your participation will involve. Please take the time to read this form carefully and feel free to ask any questions or express any concerns.

This study is being conducted to evaluate the texture and flavour of cooked white salted noodles that have been produced using wheat and various pulse flours. Five training sessions will be held starting Monday, April 11th where panelists will meet as a group to become familiar with the attributes associated with cooked white salted noodles, as well as with the scales that will be used to measure the intensities of the attributes. Twelve test sessions will then be held twice a day starting Monday, April 18th to evaluate the samples of noodles made with pulse flours.

Panelists will be identified by number and all results obtained will be kept strictly confidential. Access to information linking the panelist' names to their number will be limited strictly to the research coordinator conducting the panels. Data published will be presented as group means with no individual names used.

A $75 gift card will be given to panelists who complete **<u>all</u>** of the required training and test sessions. You are free to withdraw from the study at any time, however compensation will not be given for partial completion. You will receive a copy of the purpose of the study as well as the results shortly after the sensory testing is completed.

Your signature on this form indicates that you understand the information regarding your participation in the panels and you agree to participate. If you have any further questions or concerns, please contact Lindsay Bourré, at 984-1063 (lbourre@cigi.ca).

______________________________ ______________________

Participant's signature Date

Appendix D
Sensory Ballot

Sensory Evaluation of Cooked Noodles

Name: ________________________ Date: ________________

SMOOTHNESS: Rate the degree of surface smoothness of a noodle strand when it is evaluated in the mouth by the tongue.

R

smooth — rough

ELASTICITY: Place a noodle strand between your molar teeth. Slightly compress the strand without biting through it. Rate the degree to which the noodle returns to its original shape after slight deformation by the molars.

R

low degree
noodles do not return to their original shape — High degree
noodle returns to original shape

FIRMNESS: Place a noodle strand between your molar teeth. Rate the amount of force required to bite completely through the noodle strand.

R

soft — firm

COHESIVENESS: Chew a noodle strand to the state ready for swallowing. Evaluate the breakdown of the noodle strand in the mouth.

R

Breaks into distinct pieces — forms a mass

FLAVOUR INTENSITY: Rate the overall flavour intensity of the noodle while being chewed.

R

low degree — high degree

Comments:

AFTERTASTE: Evaluate the taste left in the mouth within 10 seconds of swallowing the noodle.

R

low degree — high degree

Comments:

Appendix E

Selected Variance Component Estimates For Sensory Data

Smoothness

Random Effect	Var. Component	Std Error	Percent of Total
Panelist (P)	0.7275	0.4957	26.46
P * Pulse Type (PT)	0.3049	0.1473	11.09
P * Blend Level (BL)	0.1336	0.0893	4.86
P * Particle Size (PS)	0.1825	0.1078	6.64
P * PT * BL	0.0254	0.1247	0.92
P * PT * PS	-0.0692	0.0794	-2.52
P * BL * PS	-0.085956	0.0753	-3.13
P * PT * BL * PS	-0.1716	0.1944	-6.24

Elasticity

Random Effect	Var. Component	Std Error	Percent of Total
Panelist (P)	0.7461	0.4821	21.227
P * Pulse Type (PT)	0.4290	0.1906	12.204
P * Blend Level (BL)	0.0249	0.1037	0.707
P * Particle Size (PS)	0.0956	0.0897	2.720
P * PT * BL	-0.1241	0.2018	-3.530
P * PT * PS	-0.2084	0.1288	-5.929
P * BL * PS	-0.0879	0.1574	-2.499
P * PT * BL * PS	-0.1221	0.3501	-3.473

Firmness

Random Effect	Var. Component	Std Error	Percent of Total
Panelist (P)	0.9207	0.5508	36.888
P * Pulse Type (PT)	0.2335	0.1031	9.354
P * Blend Level (BL)	0.0707	0.0667	2.833
P * Particle Size (PS)	0.1590	0.0898	6.369
P * PT * BL	-0.0917	0.1221	-3.674
P * PT * PS	-0.1415	0.0768	-5.670
P * BL * PS	-0.0915	0.0876	-3.666
P * PT * BL * PS	0.1158	0.2075	4.638

Cohesiveness

Random Effect	Var. Component	Std Error	Percent of Total
Panelist (P)	0.4609	0.3457	16.768
P * Pulse Type (PT)	0.5428	0.2143	19.479
P * Blend Level (BL)	0.1013	0.0855	3.686
P * Particle Size (PS)	0.0552	0.0597	2.009
P * PT * BL	-0.2693	0.1904	-9.799
P * PT * PS	-0.2085	0.1361	-7.588
P * BL * PS	-0.2200	0.1337	-8.005

P * PT * BL * PS	0.3385	0.3455	12.316

Flavour Intensity

Random Effect	Var. Component	Std Error	Percent of Total
Panelist (P)	0.7304	0.6004	17.975
P * Pulse Type (PT)	0.9780	0.3757	24.070
P * Blend Level (BL)	0.2240	0.1204	5.513
P * Particle Size (PS)	0.1023	0.1070	2.518
P * PT * BL	-0.3930	0.1974	-9.672
P * PT * PS	-0.1131	0.1764	-2.783
P * BL * PS	-0.1801	0.1599	-4.431
P * PT * BL * PS	0.1614	0.3865	3.972

Aftertaste

Random Effect	Var. Component	Std Error	Percent of Total
Panelist (P)	-0.0247	0.2348	-0.773
P * Pulse Type (PT)	1.0267	0.3614	32.153
P * Blend Level (BL)	0.1540	0.0986	4.823
P * Particle Size (PS)	0.1570	0.0982	4.918
P * PT * BL	-0.4675	0.2157	-14.639
P * PT * PS	-0.2852	0.1589	-8.930
P * BL * PS	-0.2600	0.1639	-8.142
P * PT * BL * PS	0.2965	0.4240	9.285

Appendix F

Nutrition Labels for 100% Wheat and 35% Pulse Noodles

100% CWRS Straight Grade Noodles

Nutrition Facts
Valeur nutritive
Serving Size (100 g) / Portion (100 g)
Servings Per Container
Portions par contenant

Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 250	
Fat / Lipides 0 g	**0** %
Saturated / saturés 0 g + Trans / trans 0 g	**0** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 580 mg	**24** %
Carbohydrate / Glucides 55 g	**18** %
Fibre / Fibres 1 g	**4** %
Soluble Fibre / Fibres solubles 0 g	
Insoluble Fibre / Fibres insolubles 0 g	
Sugars / Sucres 2 g	
Protein / Protéines 7 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	0 %
Iron / Fer	25 %
Folate / Folate	45 %

35% Yellow Pea Noodles

Nutrition Facts
Valeur nutritive
Serving Size (100 g) / Portion (100 g)
Servings Per Container
Portions par contenant

Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 270	
Fat / Lipides 0.4 g	**1** %
Saturated / saturés 0.1 g + Trans / trans 0 g	**1** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 610 mg	**25** %
Carbohydrate / Glucides 55 g	**18** %
Fibre / Fibres 6 g	**24** %
Soluble Fibre / Fibres solubles 0 g	
Insoluble Fibre / Fibres insolubles 0 g	
Sugars / Sucres 2 g	
Protein / Protéines 11 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	2 %
Iron / Fer	25 %
Folate / Folate	35 %

35% Green Lentil Noodles

Nutrition Facts
Valeur nutritive
Serving Size (100 g) / Portion (100 g)
Servings Per Container
Portions par contenant

Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 260	
Fat / Lipides 0.3 g	**1** %
Saturated / saturés 0 g + Trans / trans 0 g	**0** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 610 mg	**25** %
Carbohydrate / Glucides 55 g	**18** %
Fibre / Fibres 9 g	**36** %
Soluble Fibre / Fibres solubles 0 g	
Insoluble Fibre / Fibres insolubles 0 g	
Sugars / Sucres 2 g	
Protein / Protéines 13 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	2 %
Iron / Fer	35 %
Folate / Folate	90 %

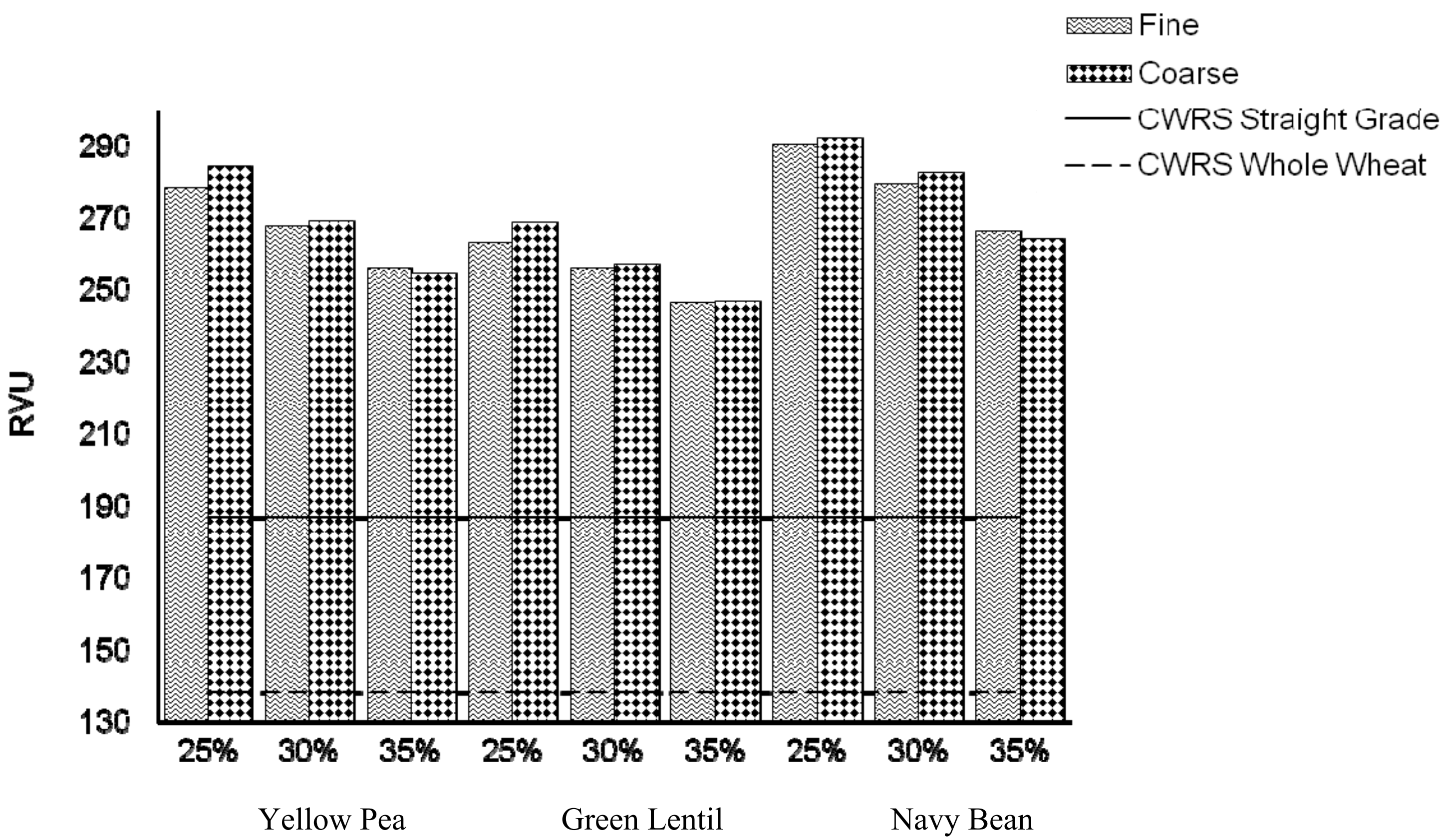
35% Navy Bean Noodles

Nutrition Facts
Valeur nutritive

Serving Size (100 g) / Portion (100 g)
Servings Per Container
Portions par contenant

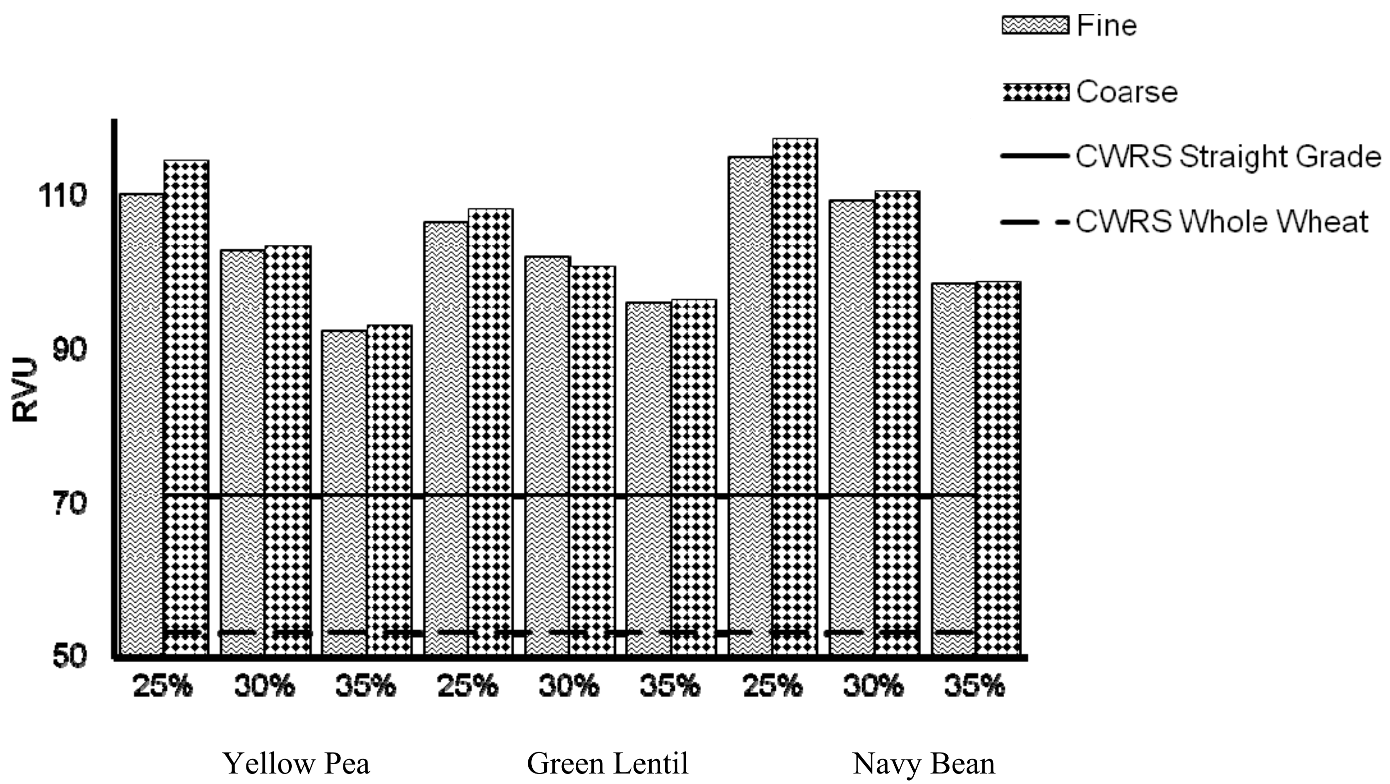
Amount Teneur	% Daily Value % valeur quotidienne
Calories / Calories 240	
Fat / Lipides 0.4 g	**1** %
Saturated / saturés 0 g + Trans / trans 0 g	**0** %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 610 mg	**25** %
Carbohydrate / Glucides 53 g	**18** %
Fibre / Fibres 6 g	**24** %
Soluble Fibre / Fibres solubles 1 g	
Insoluble Fibre / Fibres insolubles 4 g	
Sugars / Sucres 3 g	
Protein / Protéines 12 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	4 %
Iron / Fer	30 %
Folate / Folate	80 %

Appendix G



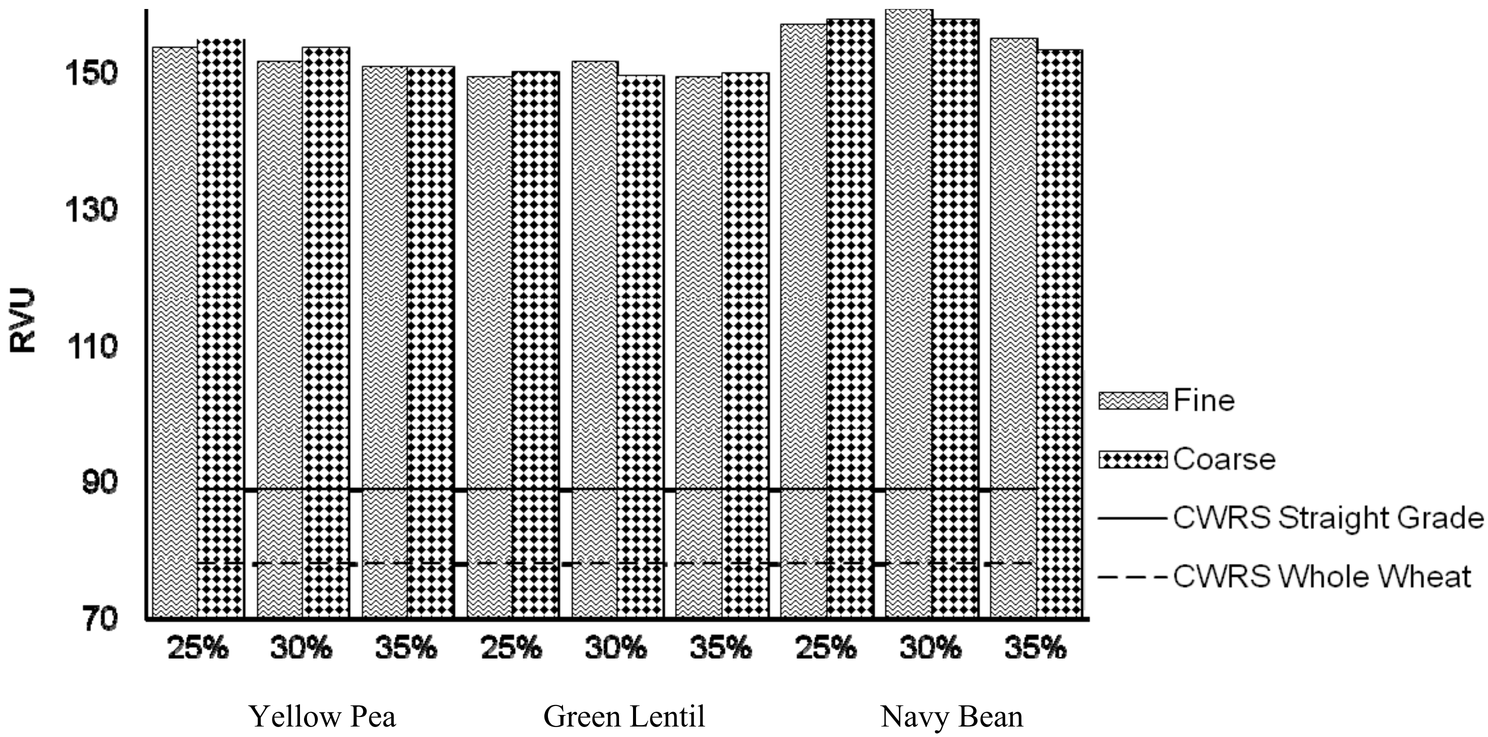
Mean Peak Viscosity Values of Blended Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

Appendix H



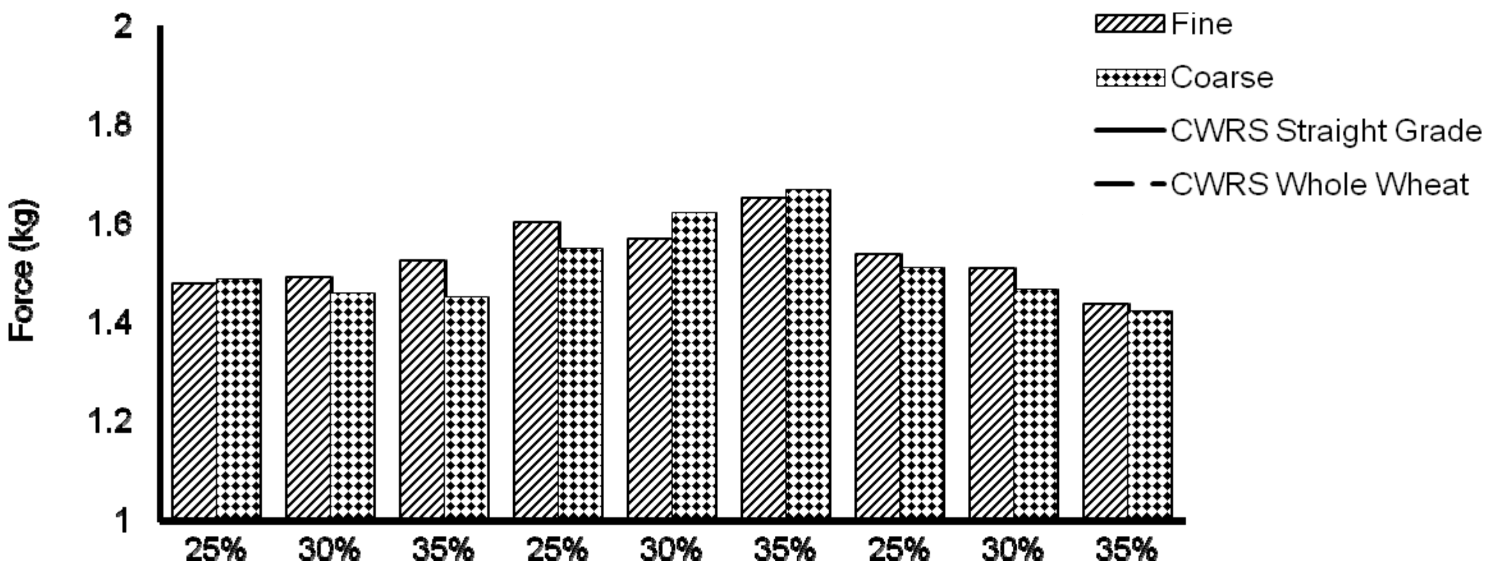
Mean Breakdown Values of Blended Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

Appendix I



Mean Setback Values of Blended Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

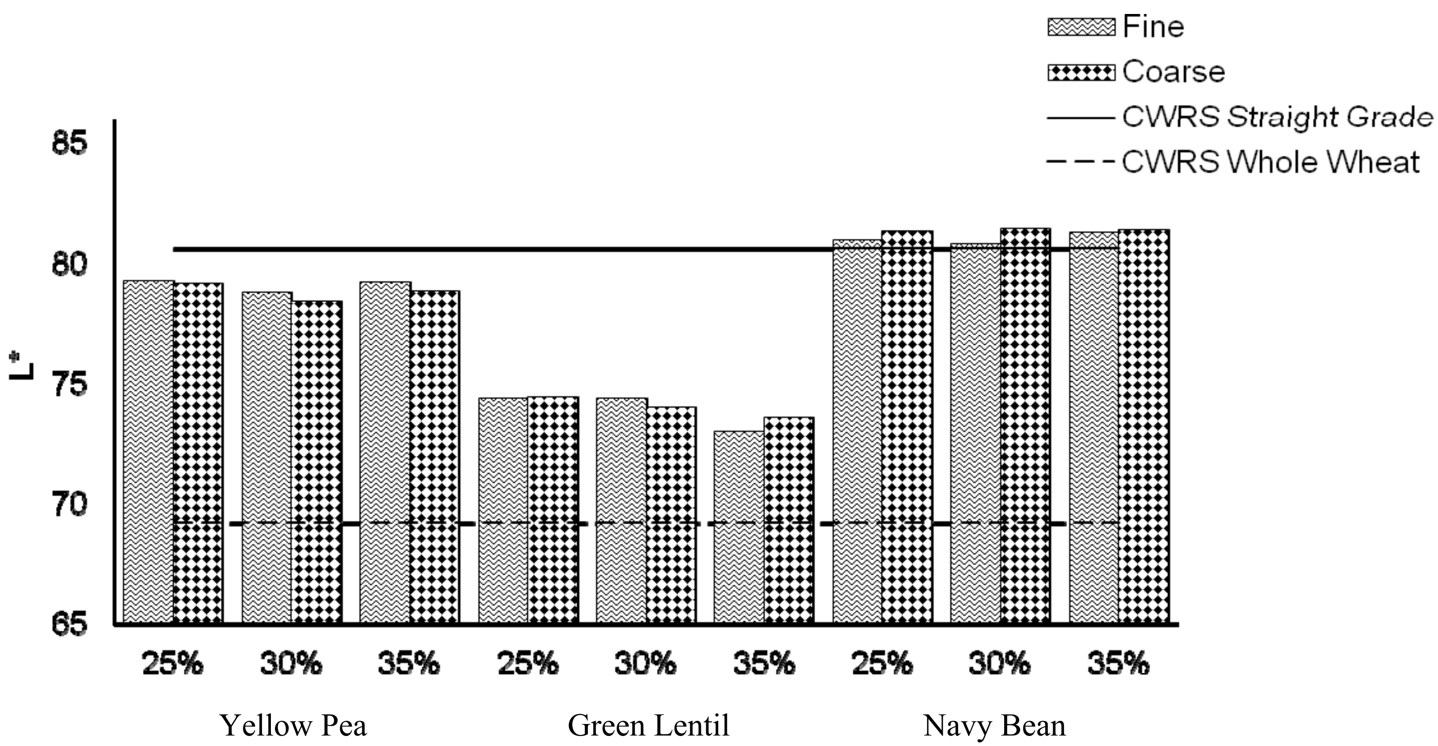
Appendix J



Yellow Pea Green Lentil Navy Bean

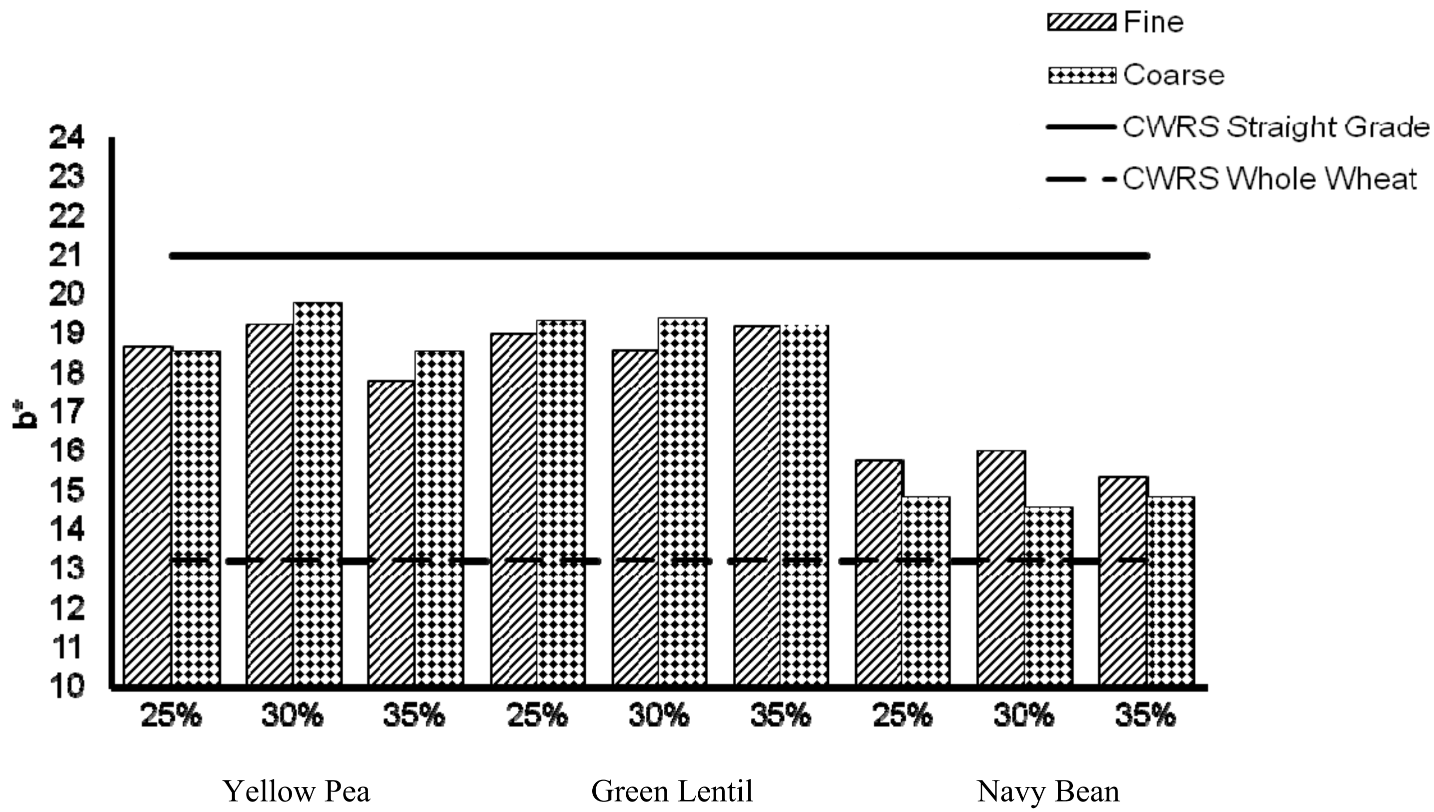
Mean Firmness Values for Dried White Salted Noodles made with Pulse Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

Appendix K



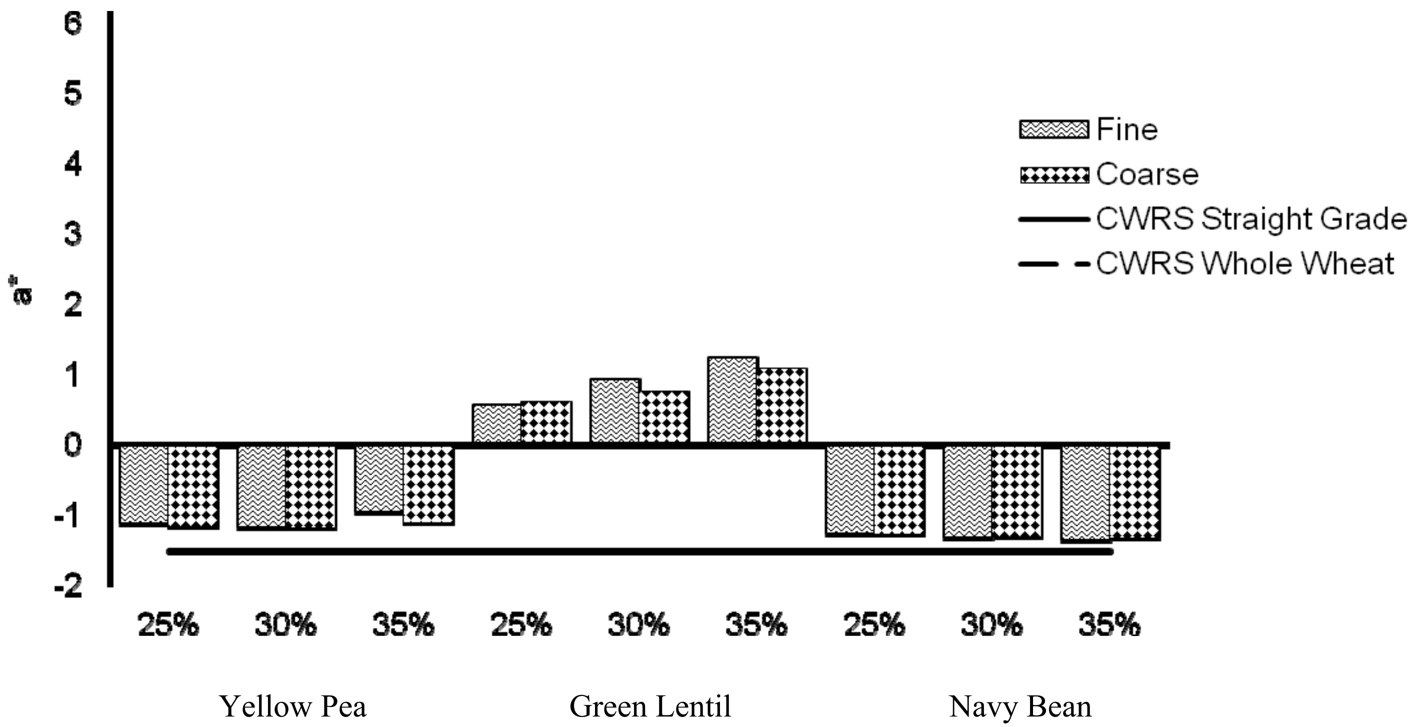
Mean L* Values for Dried White Salted Noodles made with Pulse Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

Appendix L



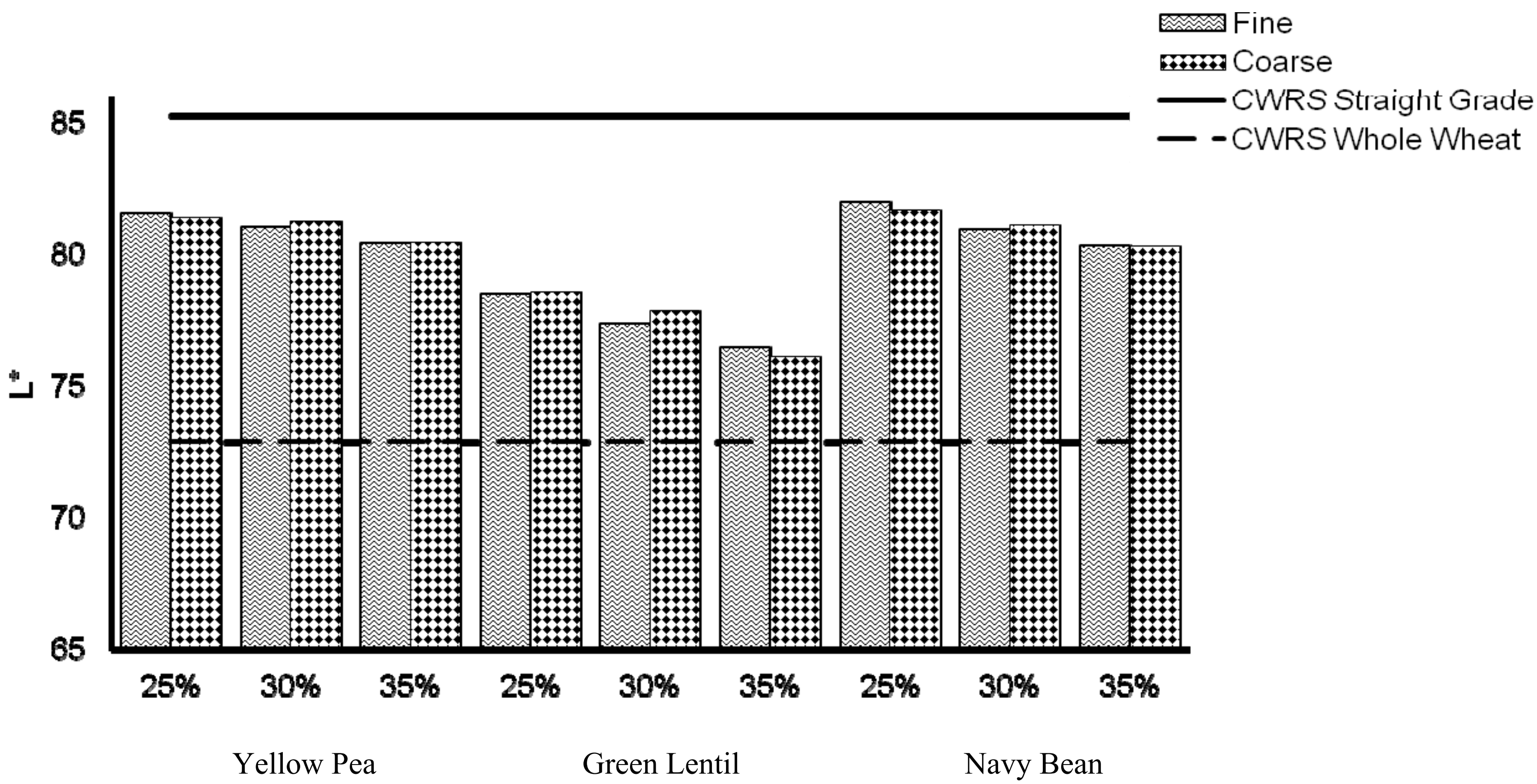
Mean b* Values for Dried White Salted Noodles made with Pulse Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

Appendix M



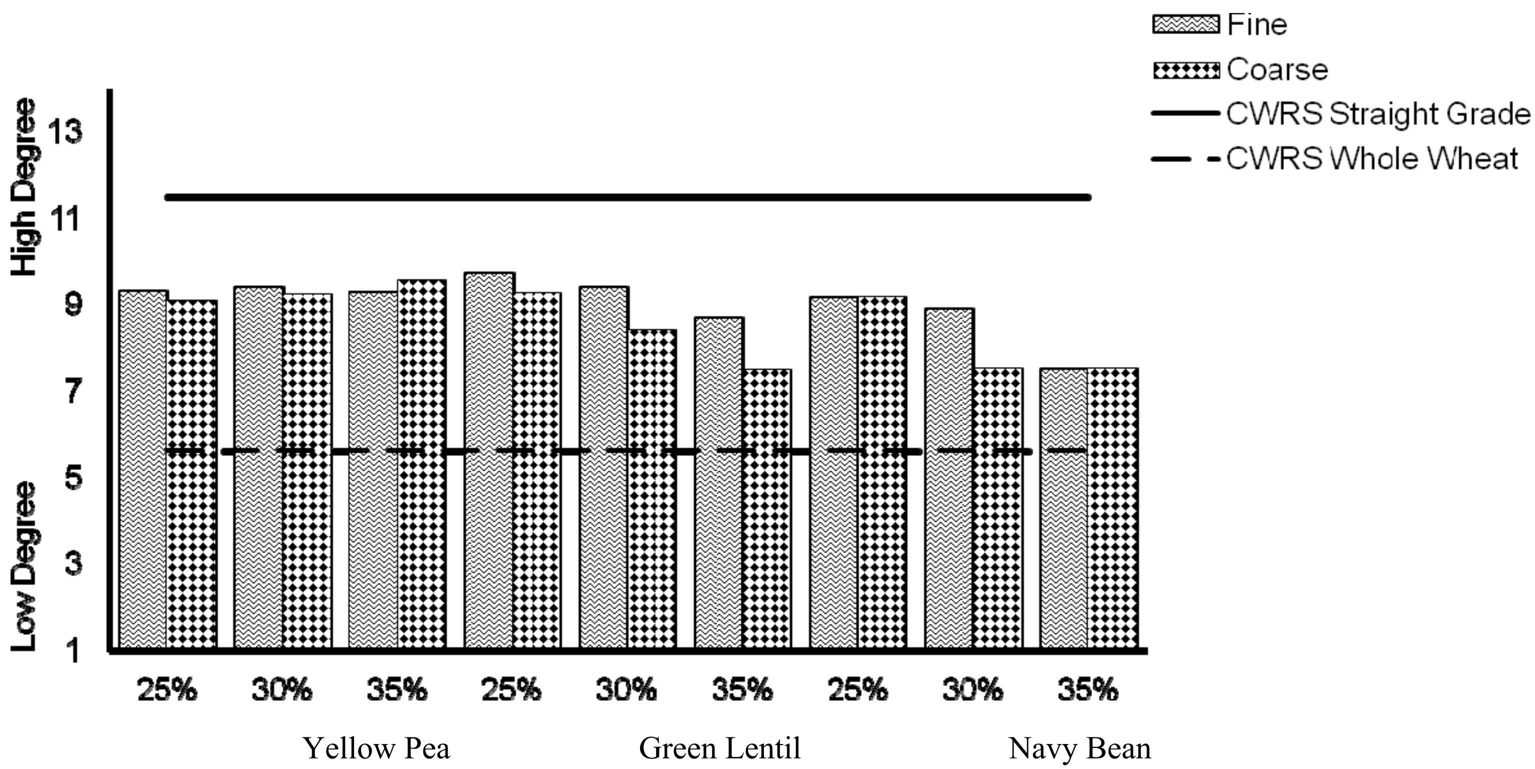
Mean a* Values for Cooked White Salted Noodles made with Pulse Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

Appendix N



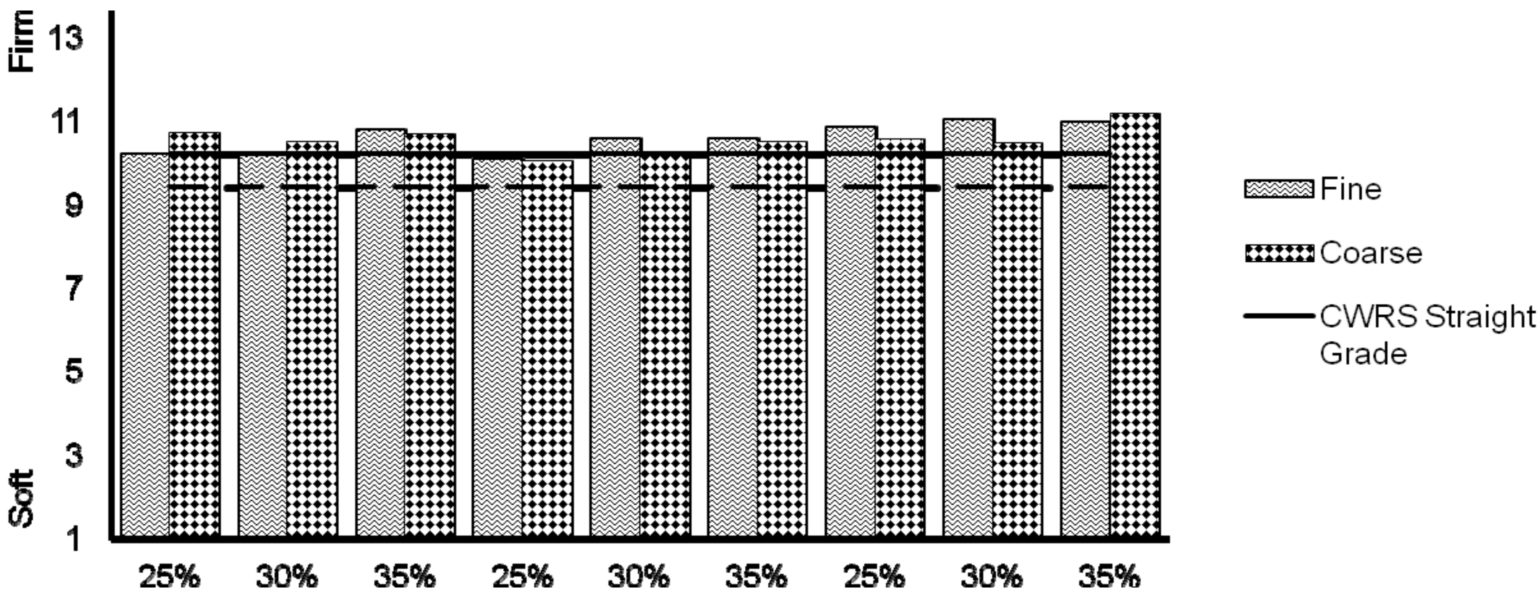
Mean Values of Sensory Scores for Smoothness of White Salted Noodles made with Pulse Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

Appendix O



Mean Values of Sensory Scores for Elasticity of White Salted Noodles made with Pulse Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

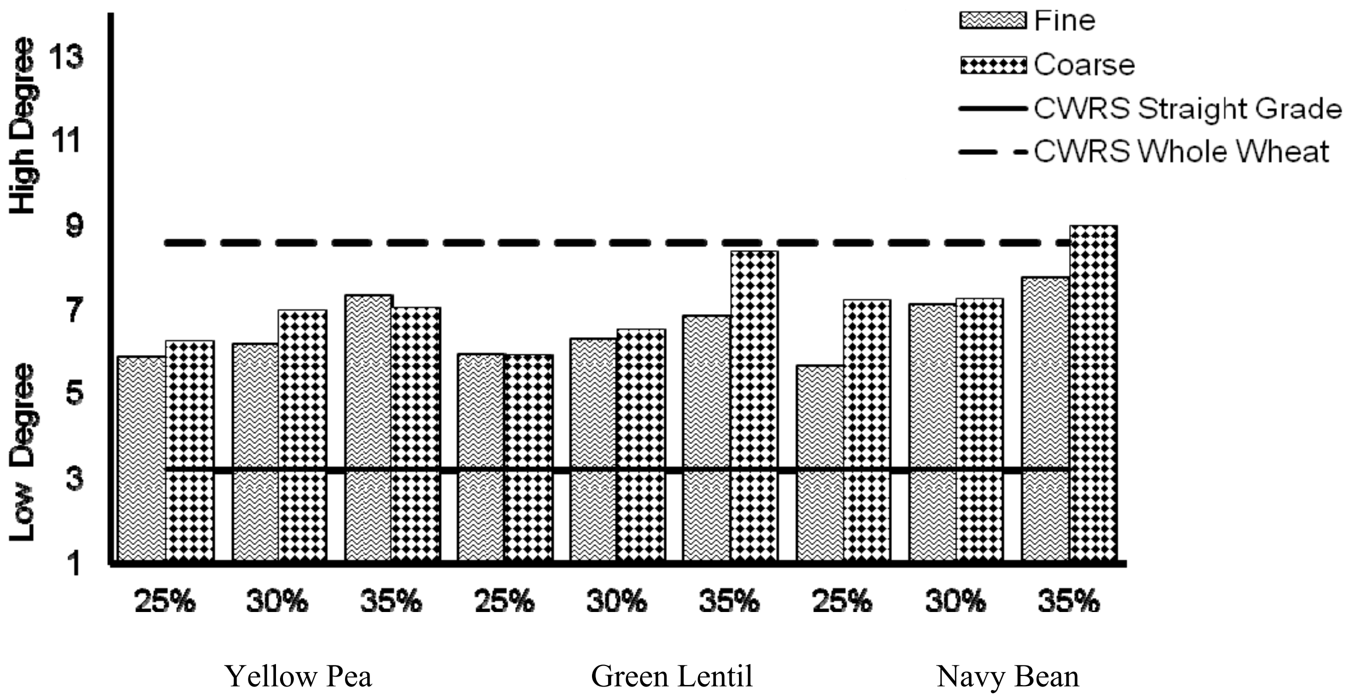
Appendix P



Yellow Pea Green Lentil Navy Bean

Mean Values of Sensory Scores for Firmness of White Salted Noodles made with Pulse Flours for all Treatments (Pulse Type x Blend Level x Particle Size)

Appendix Q



Mean Values of Sensory Scores for Cohesiveness of White Salted Noodles made with Pulse Flours for all Treatments (Pulse Type x Blend Level x Particle Size).

Appendix R

Summary of Main Effects or Interactions for Pulse Type and Particle Size for Analysis of 100% Pulse Flours

Test	Pulse Type[1]	Particle Size[1]
RVA – Peak Viscosity	S	S
RVA – Breakdown	S	S
RVA – Set Back	S	
Starch Damage	S	S
WAC		S
Colour – L*	S	
Colour – a*	S	S
Colour – b*	S	S
Trypsin Inhibitors	S	S
Phytic Acid	S	
Total Phenolics	S	

[1] S is an indication of the parameter having a main effect or being involved in an interaction of the corresponding test.

Appendix S

Summary of Main Effects or Interactions for Pulse Type, Blend Level and Particle Size of Analysis of Pulse Flour Blends

Test	Pulse Type[1]	Blend Level[1]	Particle Size[1]
Ash	S	S	S
Protein	S	S	
RVA – Peak Viscosity	S	S	
RVA – Breakdown	S	S	
RVA – Set Back	S	S	
WAC	S		
Colour – L*	S	S	S
Colour – a*	S	S	S
Colour – b*	S	S	S

[1] S is an indication of the parameter having a main effect or being involved in an interaction of the corresponding test.

Appendix T

Summary of Main Effects or Interactions for Pulse Type, Blend Level and Particle Size for Analysis of Pulse Noodles

Test	Pulse Type[1]	Blend Level[1]	Particle Size[1]
OCT	S		
Thickness	S	S	
Firmness	S	S	
Dried Colour – L*	S	S	S
Dried Colour – a*	S	S	S
Dried Colour – b*	S	S	S
Cooked Colour – L*	S	S	S
Cooked Colour – a*	S	S	S
Cooked Colour – b*	S	S	S
Trypsin Inhibitors	S		
Phytic Acid	S		
Total Phenolics	S		
Sensory Smoothness	S	S	
Sensory Elasticity	S	S	S
Sensory Firmness			
Sensory Cohesiveness	S	S	
Sensory Flavour Intensity	S	S	S
Sensory Aftertaste	S	S	S

[1] S is an indication of the parameter having a main effect or being involved in an interaction of the corresponding test.