Analysis of the Market for Canadian Hard White Spring Wheat

By

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A Thesis Submitted to the Faculty of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of

Masters of Science

Department of Agribusiness and Agricultural Economics
The University of Manitoba

©March 2002

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Abstract

Historically, Canadian farmers have predominantly grown and exported hard red spring wheat. Due to its red wheat tradition, the Canadian industry has been at a disadvantage to capture the fast growing white wheat markets. Canadian hard white spring wheat (HWS) breeding programs however, have been established to meet this demand. If the quality characteristics inherent to this new wheat are appropriate for the specified end products, then the Canadian industry could effectively penetrate markets not adequately accessed by traditional red wheat. The study examines the usage potential of HWS in various selected end products based on its contribution to the flour.

A least-cost linear programming model was used to determine the HWS content in flour blends which meets the specified quality standard for that product. Blends simulated were: pan bread and specialty bread flours to represent the domestic market, while Asian noodle and flat bread blends represent the export market. Quality parameters used in the linear program were: flour protein content, Farinograph absorption, Liquefaction Number, flour extraction, flour color, and Farinograph stability. Simulations of HWS acceptance into the flour blends was performed on three market settings representing conditions of low, average, and large price differentials between high quality and lower quality wheat.

It was determined that HWS is a suitable and cost effective ingredient in pan bread flour blends. HWS would comprise a 32.8% share of pan bread flour blends at a US$2.69/t premium to high quality red wheats, and a 56% share at price equivalency. For higher strength specialty breads, HWS could comprise a 34.9% share of the flour blend at a price premium of US$4.63/t to high quality red wheat. It was determined that a high quality HWW developed in Canada would achieve limited success in Asian noodle flour blends as lower protein white wheats would be more suitable. No price premiums would be realized in this market. Hard white wheat could comprise significant portions of flat bread flour blends, but its estimated usage at premium prices was limited, as lower quality wheats are easily substituted into the blends, especially in market settings where price premiums for high quality wheat are large.

Acknowledgements

I would like to thank my advisor Dr. Daryl Kraft, Head, Department of Agribusiness and Agricultural Economics for the efforts he made to ensure the completion of this study, especially through times when other concerns were a priority. I would also like to thank the members of my examining committee, Dr. Brian Oleson, and Dr. Harry Sapirstein, for agreeing on short notice to act as external examiner.

Special thanks to Mr. Ashok Sarkar, Head, Milling Technology, CIGI, for sharing his time and expertise to explain the fundamentals behind the wheat milling simulation and linear program at CIGI. Also thanks to the Market Analysis Department at the Canadian Wheat Board for the valuable information on wheat and wheat markets, and for the valuable time spent in your department.

I would like to thank The Canadian Wheat Board, Manitoba Rural Adaptation Council, and the Malchy Grain Company, for their generous financial support during the completion of this study.

Finally, thanks to my wife Bonnie, who showed enduring patience and support during the course of this study.

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1.1 Introduction

Wheats differ according to their inherent quality characteristics. These characteristics are important in determining the usage and demand for a specific wheat. Wheat is chosen based on characteristics that will serve in producing a desired end product. For example, in general, hard wheats contain attributes consistent with producing loaf breads, durum wheats possess characteristics suitable for making pastas, and soft wheats have characteristics suitable for making pastries. Of course, wheats can be blended together to make desired flour blends for most any product which requires specific flour quality specifications. Wheat flours are blended to precise specifications in order to meet the required characteristics desired by end product makers. Millers are responsible for blending the wheat to satisfy the desired flour specifications of customers. These blends are adequately specified in terms of characteristics to maintain an extremely uniform product, which is an important consideration for bakeries.

The following chapter provides a description of hard white spring wheat (HWS) as it differs from wheats traditionally grown in Canada. The chapter describes HWS in terms of physical properties, as well as a description of the traditional markets for HWS with implications as to the objectives underpinning the development of HWS in Canada.

For most exporting countries, extensive wheat quality and flour quality tests are carried out. These tests allow for objective quality comparisons to be made. Wheat tests typically involve weight tests, protein content analysis, ash content analysis, as well as a test for kernel soundness (Falling Number). Milling tests on the wheat determine the hardness, and extraction capabilities of the wheat. Flour tests are carried out to determine the wheat flour's suitability for various processes and end products. These tests are categorized by Farinograph tests, which determines mixing properties of flour, and Extensigraph and Alveograph tests which determine the strength of flours by testing flour elasticity and resistance to stretching. Often a baking test is also done to determine the quality of end products achieved by the wheat.

Table 1.1 indicates some of the quality tests typically undertaken to determine a wheat's functional capabilities. Many of these characteristics are important in analyzing the potential penetration of Canadian HWS into the domestic and export markets. For illustration's sake, four types of wheat, both Canadian and Australian, have been selected for comparison based on their potential competitive position with HWS. These quality tests on Canadian wheat are performed at the Grain Research Lab (GRL) in Winnipeg, while Australian wheat is tested at The Academy of Grain Technology (AGT) in Australia. Analysis of wheat and flour characteristics for both Australia and Canada are carried out using testing methods approved by the American Association of Cereal Chemists (AACC), and the Standard Methods of the International Association for Cereal Science and Technology (ICC). Such analysis is important in order to make comparisons between different types of wheat. Most of these testing methods are standardized across countries, however, some of the milling and baking tests are not. Wheat testing procedures are becoming more advanced and common in the industry. Many quality measures are now explicitly specified in contracts with buyers in the domestic and export markets. Some of the more commonly measured characteristics are noted for comparison in Table 1.1.

Table 1.1. Comparison of Characteristics of Australian and Canadian Wheat (1996-97)

	No.1 CWRS 13.5	Australian Prime Hard (S.NSW)	Australian Standard White	CPSW
Wheat				
Test weight (kg/hl)	81.3	83.0	83.5	81.6
1000 kernel weight (g)	30.0	38.4	32.6	34.9
Protein content (%)	13.7	13.7	9.4	11.5
Ash content (%)	1.58	1.39	1.27	1.46
Falling number (sec)	385	479	375	390
Milling				
Flour Extraction (%)	75.1	76.9	75.9	75.1
Flour				
Protein (%)	13.0	12.6	8.2	10.6
Wet gluten content (%)	34.1	35.0	20.0	28.1
Ash content (%)	0.47	0.45	0.43	0.48
Color grade	-1.7	-.80	-2.1	-2.1
Farinograph				
Water absorption (%)	65.0	63.3	58.0	60.2
Development time (min)	5.0	6.0	3.8	3.5
Stability (min)	11.0	14.6	7.4	4.5
Extensigraph				
Length (cm)	22.0	21.0	16.5	22.0
Maximum height (BU)	525	430	400	340
Area (cm^3)	160	127	92	105
Alveograph				
Length (mm)	110	88	77	118
P(height x 1.1) (mm)	112	136	88	70
W, x 10^{-4} joules	425	370	210	221
Baking Test				
Loaf volume (cm^3)	1105	775	670	640

Sources: 1996-97 Australian Wheat Board Crop Report
1996-97 Grain Research Lab

1.2 Description of Hard White Spring Wheat

Canadian hard white spring wheat (HWS) is a type of wheat that is expected to show quality characteristics similar to Canada Western Red Spring (CWRS) wheat, the standard for high quality bread wheat in Canada. Like CWRS, HWS is expected to be a high protein, high gluten strength wheat. Only recently has Canada begun to produce a hard white spring wheat. Common wheat production on the Canadian prairies has traditionally consisted of hard red spring wheats, and to a lesser extent, soft white spring wheats. The hard white spring wheat being developed, while suitable for whole wheat pan breads, is also targeted towards Asian style noodle production. These noodles generally require the bright color and firm texture that HWS potentially provides. The second thrust behind the development of HWS is the Middle East flat bread market. These breads also require a white end product at relatively high flour extraction rates that HWS can provide.

The main shortcoming of CWRS for some end products is the red seed coat. Potentially, HWS flour could be used in all applications where hard red wheat is used; the major difference is that, for high extraction rates, the color of the flour is brighter using HWS compared to hard red wheat. Canada Western Red Spring wheat flours tend to show flecks of bran at extraction rates of about 73%, whereas white wheat typically can achieve higher extraction rates for same degree of flour color. Many export markets prefer wheat with a white seed coat for this reason. White wheat bran flecks are not as visible as red wheat bran flecks at extraction rates above 73%, therefore, HWS would appear to have an advantage of producing a brighter flour and hence, a brighter end product color. In any case, the quality of flour is not significantly different, but color becomes a visible factor. Canada Western Red Spring would require a bleaching process to achieve the same degree of whiteness. The development of a HWS would essentially eliminate the bleaching process.

Various tests on hard white wheat grown in Canada and the U.S. have shown that hard white wheat has an extraction advantage over comparable red wheats of anywhere between 1 to 5%. Therefore, for products that demand white flour in production, hard white wheat would appear to have a comparative advantage over hard red wheats, considering that all other characteristics are equivalent.

Hard white wheats are also reputed to be sweeter tasting than red wheats when utilized in loaf bread production. Although this notion has been subject of some debate, reports have indicated that red wheats have a more bitter flavor due to phenolic compounds of the bran, compared to white wheats which have lower amounts. Because of this, it is argued that less sugar is required in the bread making process bringing down production costs even further[1]. However, in a study by Mark Ingelin et al. (1998), a 24-member panel of tasters compared the tastes of near-isogenic red and white wheats, suggested that there was no detectable flavor difference between the two types of wheat[2]. The same study showed little difference in either dough properties or loaf properties; the only properties distinguishably different were attributable to difference in bran color.

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[1] William Lin and Gary Vocke, "Hard White Wheat: Changing the Color of U.S. Wheat?" *Agricultural Outlook*, (Economic Research Service, USDA, August 1998).

[2] Mark Ingelin, et al. *Comparison of Near-Isogenic Red and White Wheat Selections*, (Winnipeg: Agriculture & Agri-Food Canada, Cereal Research Centre,1998).

Considering this evidence, HWS theoretically offers the potential for improved color and taste in wheat flour products, as well as potentially higher margins for millers.

Historically, the main disadvantage of hard white wheat, as with all white wheats grown in Canada, has been a lack of sprouting resistance compared to red wheats. Currently, one of the main goals of breeders of HWS is to achieve sprouting tolerance in HWS lines equivalent to that of CWRS wheat. It has been speculated that the major reason why hard white wheat is not grown in North America is that previously, it was rejected due to inferior sprouting resistance compared to red wheat. In the end, the success of HWS will be determined by the market. In order to be successful, HWS will have to demonstrate superior milling and baking properties, and /or agronomic superiority, leading to a price premium compared to CWRS.[3]

1.3 Markets for Hard White Wheat

The most obvious market for high quality HWS is the domestic North American bread market. In Canada, the past ten years have seen on average 2.5 mmt of wheat ground for flour domestically giving total flour tonnage of 1.9 mmt. The U.S. tonnage of wheat milled for flour is approximately 22.6 mmt, making 16.8 mmt of flour. Therefore, the total North American market size is 25.1 mmt of wheat ground for flour, producing 18.7 mmt of flour. This amount, minus flour exports tonnage indicates the true domestic disappearance of flour. Canada's domestic usage of wheat flour is on average 1.6 mmt,

[3] *The Market Competitiveness of Western Canadian Wheat.* (A joint study by the Manitoba Rural Adaptation Council Inc. and the Canadian Wheat Board. 1999).

while the U.S. uses 16.1 mmt, for a total of 17.8 mmt of flour required for the North American flour market. The largest portion of this market is for large volume loaf breads, with a smaller portion for rolls, buns, and confectionery products. Assuming that HWS achieves agronomic advantages, is accepted by producers, and consistency of quality and supply are realized, HWS is likely to find acceptance in the domestic milling market due to its potential economic advantage over red wheat, as well as its potential suitability to produce whole wheat breads.

In terms of export markets, HWS would appear to be especially suited to markets such as noodle and flat bread markets. The South East Asian market has the highest demand for high quality wheat imports, and also demands the characteristics inherent in HWS. All indications thus far are that HWS could adequately enter key high quality wheat markets, assuming that the quality characteristics are similar to that of CWRS. It is understood that for these markets, there is a general rule that about half of wheat flour is used for noodle production and the other half consisting of baked goods. While not all wheat purchased for this market is high quality, the market size is large. The size of the noodle market in Asia is estimated to be around 20 mmt.[4]

The Middle Eastern and Indian Subcontinent flat bread market is also a potential export market for high quality wheats as these products tend to require slightly higher protein levels. This market is estimated to be around 20 mmt in size as well.[5]

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[4] David Frey, *The Wheat Scoop: Hard White* Wheat *Conference* (accessed 1998); available from http://www.kswheat.com/wheatscp/1998/03-19-98.html; Internet.

[5] *Ibid.*

In terms of exports, both the noodle and flat bread producing regions are important growth markets. The Canadian Wheat Board (CWB) forecasts that these regions will see large increases in high quality wheat imports from North America. For Canada, the CWB sees high quality wheat exports to Asia-Pacific to increase from a five-year average of 2.26 mmt to 3.94 mmt in 2007/08. Exports to the Middle East region are expected to rise from a five-year average of 0.27 mmt to 0.81 mmt in 2007/08.[6]

Questions remain whether hard white wheats would substitute for hard red wheats in export markets and to what extent, as well as questions of whether certain countries not currently involved in importing high quality wheat on a regular basis will be inclined to do so with the introduction of hard white wheat.

1.4 Historical Background on White Wheat Production and Exports

1.4.1 The Canadian Experience

White wheats are produced primarily in Australia, India, Pakistan, the U.S. and Canada, although white wheat suitable for bread making is produced only in the three major exporting countries, Australia, the U.S. and Canada. White wheat production in these three countries makes up about 5% of total world wheat production. Historically, Canadian white wheat production has been of the soft wheat varieties, typically used for biscuit, cake and confectionery applications. For the most part, this includes Canada

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[6] L.J. Sawatsky, and P.J. Finn, *CWB Quality Wheat Demand: Forecast to 2007-08*. (Winnipeg: Printcrafters, 1998), 4-10.

Western Soft White Spring (CWSWS) which is produced mainly in the province of Alberta, and soft white winter wheats which are grown in eastern Canada.

Canada's recent attempts at capitalizing on the higher quality white wheat market has lead to the development of white wheats which have been grouped in the class Canadian Prairie Spring White (CPSW). While it is not a true HWS, CPSW is harder than soft white wheat and is capable and suitable to meet many end product characteristics in which HWS would also be competitive. It can be used alone or in blends for the production of many types of noodles, flat breads and some household flours[7]. According to the CWB, "the principal markets for CPSW wheat are in Asia and the Middle East, with some exports to South America as well. Pakistan and Indonesia accounted for approximately two thirds of the sales for CPSW (in 1994-95), although demand is quite variable."[8]

The first of this class was Genesis. This wheat seemed to suit most of the needs of the market, but some of the characteristics were less than desirable, therefore, this wheat did not realize it's expected potential. Genesis did not have the required color stability, that is, the color of the product deteriorated as the practice of making dough proceeded. Also, Genesis was deemed by millers to be too soft for an ideal milling situation. Millers generally find that harder wheats are more desirable to mill, and Genesis did not display the required hardness. Improvements were eventually made on Genesis and brought

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[7] *The Market Competitiveness of Western Canadian Wheat.* (A joint study by the Manitoba Rural Adaptation Council Inc. and the Canadian Wheat Board. 1999).

[8] *Ibid.*

forth the new cultivar AC Karma. Color stability was found to be improved compared to that of Genesis, but Karma retained some of the less than desirable attributes of Genesis. Specifically, it had the same approximate dough strength as Genesis, which was not strong enough for market demands. Karma is a medium hard, medium protein, medium gluten strength wheat. The newest CPSW variety to date is Vista. Vista sees further improvement on AC Karma in that gluten strength is higher, comparable to that of HWS. Canada Prairie Spring White's failure to compare functionally with Australian HWS and meet customers requirements is evident in its price relative to Australian Standard White (ASW), Australia's chief export wheat, which sells at a significant premium to CPSW.[9]

Hard white wheat differs the most from CPSW in that the protein content is significantly higher, and greater gluten strength results in greater stability. Canadian efforts to breed high quality hard white wheat is proceeding on two fronts. The first is developing a HWS from parent strains of CWRS, selecting for white seed traits[10]; the second is to develop a HWS from CPSW by increasing the protein content and gluten strength, as well as selecting for other appropriate characteristics such as low levels of polyphenol oxidase (PPO). In either case, the desired end result is to achieve a strain of white wheat which approximates the overall quality characteristics of CWRS. It is expected that Canada is between two to three years from wide-scale production of HWS.

[9] The Canadian Wheat Board, *Demand Outlook for Canadian Wheat.* (Market Analysis Dept. 1996).
[10] T. F. Townley-Smith, *Development of Hard White Wheat for the Canadian Prairies* (Winnipeg: Cereal Research Centre, Agriculture and Agri-Food Canada, 2001).

1.4.2 The Australian Experience

At the present time, the major exporter of hard white wheat is Australia, which grows hard white wheat almost exclusively. On average, Australia exports 75-80% of production. These exports are destined for more than 40 countries mostly in Asia and the Middle East, especially China, Egypt, Japan, Iran, Indonesia, Malaysia, and South Korea. Australia has extensive knowledge of South East Asia and Middle Eastern markets, and have developed their export wheat programs to suit these markets, allowing them to gain significant market shares. Australian wheat exports have a good reputation in these markets as being clean, dry, consistent, and suitable for their end usage. Australian hard white wheat is used for a wide range of applications. It is used primarily for Asian noodles and Middle Eastern and Indian-style flat breads, but also is capable of producing high volume breads, steamed breads, and European-style hearth breads

Australian Standard White (ASW) is Australia's principal wheat subclass. Protein levels range from 7.5-11.5%, making this wheat very suitable for noodle flour and flat bread flours. Grain hardness is considered to be intermediate (medium hard to hard) and is comparable to some CWRS varieties. Exports of ASW represent about 70% of Australian wheat exports (96-97). The closest Australian wheat in terms of characteristics expected of Canadian HWS is Australian Prime Hard (APH), Australia's top quality wheat. This wheat is quoted at 13% protein, and makes up about 8% of the total crop in Australia. Another type of Australian wheat is Australian Hard Wheat (11.5% protein), which is very similar in hardness to APH. On average, it comprises approximately 14% of total wheat production. Australian Premium White (10% protein), and Australian Noodle Wheat make up the other classes of Australian wheat. If Canadian HWS can be developed to be a close substitute for Australian white wheat, then there appears to be an excellent opportunity for sales to Asia and the Middle East. Table 1.2 shows recent export statistics for Australian wheat exports into important Pacific Rim and Middle East markets. These markets are historically the most important to Australia; where they have cultivated extensive market understanding, and have gained a leading market share of imported wheats. On average, 58% of Australian white wheat exports are destined for markets in Asia-Pacific. Another 25% are destined to the Middle East and 14% for Africa.[11] Some of these markets have been important for Canadian exports as well, and could increase in importance if Canadian wheat flour could be produced to better suit these markets. The CWB projects that the Middle East and African markets will become increasingly important for Australian exports, suggesting a substantial growth in demand for hard white wheat on the world market.

Table 1. 2. Australian Exports of Wheat and Wheat Flour into Various South East Asian and Middle East Countries ('000 tonnes)

	China	Japan	Indonesia	Malaysia	Korea	Egypt	Iran
1988/89	1381	1040	939	414	134	1959	1391
1989/90	1062	1209	1067	658	395	1953	1617
1990/91	1425	1173	930	655	1532	1427	1788
1991/92	290	1053	901	420	414	1806	608
1992/93	610	1041	975	506	749	1088	1104
1993/94	1131	1161	1090	769	1437	1313	2380
1994/95	925	1269	1149	577	669	383	751
1995/96	2272	1135	1696	676	700	745	1579
1996/97	209	1073	1979	730	698	1886	3632
1997/98	195	1172	2355	679	771	619	486

Source: Canada Grains Council Statistical Handbook (2001).

[11] The Canadian Wheat Board, *Demand Outlook for Canadian Wheat* (Market Analysis Dept., 1996).

The CWB has made the following market projections regarding Australian wheat exports and market share[12]:

The CWB projects total exports of high protein APH wheat to decline by 12% (base period 1990-1994), to 285,000 mt by the year 2004-05. However, exports of mid-protein AH are projected to increase by 157% to 2 mmt, while exports of lower protein ASW are projected to increase 35% to 12 mmt by 2004-05. The CWB anticipates that mid-protein flat bread markets such as the Middle East and Africa will account for the majority of the increase, partly due to rapid population growth, as well as increased deregulation of the milling industries in these countries. The CWB also anticipates that the demand for higher quality wheat will increase in Asian markets with technological advances that are occurring in their milling industries.

1.4.3 The United States of America (U.S.) Experience

Similar to Canada, most white wheat produced in the U.S. is of the soft white variety, and used mainly for production of biscuit and confectionery products[13]. The major markets are in the Middle East, where it is used for various flat breads, and Asia-Pacific, where it is used for confectionery products and other applications such as all-purpose flours and some noodle flours.

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[12] *Ibid.* page 13.

[13] William Lin and Gary Vocke, "Hard White Wheat: Changing the Color of U.S. Wheat?" *Agricultural Outlook*, (Economic Research Service, USDA, August 1998).

The development of hard white wheat in the U.S.A. is an important topic to consider since its situation somewhat parallels that of Canada. Both countries are traditionally red wheat producers and exporters, with a growing hard white wheat development program. A look at the U.S. situation provides insight to the budding Canadian situation in terms of hard white wheat production in the future.

Currently hard white wheat production in the U.S. accounts for only a very small percentage of the total wheat acreage, but the popularity of this new type of wheat is growing exponentially. Currently, about half of U.S. hard white wheat acreage is seeded to spring varieties, mainly in the Northern Plains and Pacific Northwest, and half is seeded to winter varieties, in the Great Plains region. Presently, hard white wheat accounts for 2-3% of U.S. white wheat acreage and only 0.2% of total U.S. wheat acreage.[14] American producers are being encouraged to grow hard white wheat only in drier areas as sprouting damage is still a concern. Table 1.3 indicates the approximate size of hard white wheat acreage in the U.S.A.

Table 1.3. U.S. HWS Seeded Acres by State (1998)

State	Acres Seeded
Montana	40,500
Colorado	20,000 – 50,000
Kansas	10,000 – 20,000
Idaho	15,000
California	12,000
Oregon	< 2,000
Others	750
Top 5 States	97,000 – 137,000

Source: USDA, Economic Research Service

[14] William Lin and Gary Vocke, "Hard White Wheat: Changing the Color of U.S. Wheat?" *Agricultural Outlook, Economic Research Service*, USDA, (August 1998).

Popular U.S. sentiment is that hard white wheat is the future of wheat production in the U.S.A. The American agricultural industry is investing much of its research and development efforts into the advancement of hard white wheat production. Many of the nations leading wheat breeders are devoting between 40-75% of their wheat breeding programs to HWS, up from 10-25% in the 1980's, and for the first time, the top performing lines of wheat being bred are of hard white wheat varieties, out performing red wheat varieties by 3-4 bushels per acre.[15] Much of the current breeding research being done is to improve hard white wheat susceptibility to sprouting. Several large agricultural corporations have also committed research and development capital into hard white wheat, along with identity preserved production programs. Interest in hard white wheat development is evident in that some private companies have up to half of their new lines of wheat being hard white varieties.[16]

Insufficient quantities have been a stumbling block to hard white wheat advancement so far, and it is expected to take 2-3 years for hard white wheat to reach the commercial production stage. The rate of expansion in hard white wheat acreage will initially be limited not only by producer acceptance, but by the availability of certified seed. However, the U.S.A. is expecting major increases in hard white wheat acreage in the future. As an example, the state of Kansas expects to have 1 million acres seeded to HWS by 2003. Major questions remain about hard white wheat ability to replace HRW in traditionally HRW dominated areas, although American researchers, breeders, and

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[15] William Lin and Gary Vocke, *Hard White Wheat: Changing the Color of U.S. Wheat?* (Economic Research Service, USDA, August 1998)..

[16] Frey, David. *Privately Funded Hard White Wheat* (accessed 1998); available from http://www.kswheat.com/wheatscp/1996/02-15-96.html; Internet.

producers have already projected that Kansas will move from a primarily HRW state to a HWW state within the next 10 years.[17]

In terms of potential end uses for U.S. hard white wheat, three specialty products have been identified: whole wheat bread, tortillas, and oriental noodles. While the domestic market for whole wheat bread is one motivation behind hard white wheat development, losses in export market share to Australian varieties in the 20 million tonne market for noodles is a major factor in the U.S. hard white wheat program to increase hard white wheat production.[18] Another potential export market is the Middle East and Indian Subcontinent flat bread market. It has been estimated that the market for flat breads could be as large as 20 mmt, however, this market tends to be more price sensitive than the Asian noodle market.[19]

American varieties of hard white wheat are expected to compete with mid-protein Australian wheat (AH, AP, and Noodle) in international markets dominated by Australian wheat exports. These varieties will have a lower protein level than APH (quoted at 13%), but greater than ASW (about 9%). Currently, the U.S. is working at improving the color stability of hard white wheat flour when used in noodle production to equate with the quality standards set by Australian wheat.

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[17] The Kansas Wheat Commission *News Release: Comments on White Wheat Release Extended.* (accessed 1998); available from http://www.kswheat.com/wheatscp/release/HWS_comments.html; Internet.
[18] David Frey, *Hard White Wheat Conference* (accessed 1998); available from http://www.kswheat.com/wheatscp/1998/03-19-98.html; Internet.
[19] *Ibid.*

In terms of the U.S. domestic market, hard white wheat is also targeted for production of wheat tortillas, which currently double the number of corn tortillas that are produced, and "wrap" food products, which have become popular in the mainstream fast food industry. Mexico has also been identified as a potential export market for wheat tortillas.[20]

U.S. hard white wheat production is currently regarded as a niche market. Of late, much of the U.S. hard white wheat production is contracted under identity preservation programs, with special binning in selected collection facilities (elevator or miller). Domestic millers have been contracting with U.S. growers at premiums of US$0.25-0.35/bushel over HRW in 1998[21].

According to Lind and Vocke (1998), the U.S. hard white wheat harvest currently requires special binning and identity preservation programs as mixing would incur a price discount, eliminate the extraction rate advantage, and possibly lower the grade if the level of "contrasting classes of wheat" exceeds the allowable limit.

As for the American situation, it is not expected that producers will receive more than a modest premium for hard white wheat, due to market expenses associated with segregation. Therefore, hard white wheat has to show an agronomic advantage over HRW to compete and grow in popularity. It is predicted that large-scale segregation would be required from the producer to the end user until larger quantities of hard white

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[20] William Lin and Gary Vocke, "Hard White Wheat: Changing the Color of U.S. Wheat?" *Agricultural Outlook*, (Economic Research Service, USDA, August 1998).

[21] *Ibid.*

wheat would allow for economies of size and return a greater profit to producers. As well, exports are expected to remain minimal until supplies are sufficient to provide a consistent quality and reliable quantities to importers.

1.5 Objectives of the Study

Matz (1996) states that when performing tests for flour characteristics, "in order for test results to be meaningful... the intended use of the grain must be known"[22]. It would therefore be prudent to analyze the potential for HWS usage by studying possible end products which could have a preference for HWS flour.

Hard white wheat could conceivably be used for most any end use product, but, as will be discusses later, there are two main focuses of the development of HWS in Canada. The first is to have a hard white wheat that is suitable for domestic pan bread production, and the second is to have a wheat preferred in the emerging Asian noodle and Middle Eastern and Indian Subcontinent flat bread markets. In order to determine which products Canadian HWS could be applied, the method of analysis would therefore be to analyze the following:

1) the markets where Canadian hard red spring wheat (CWRS) is used and could potentially substituted with HWS, and

2) the end products where white flour is demanded, and where hard white wheat is currently used

Millers produce a wide variety of flour products. In general, large international millers manufacture vast quantities of multi-purpose flours while smaller mills fill the demand for more specialized flours. As well, large international millers ordinarily use straight run wheat to produce its flour types, whereas smaller mills tend to incorporate a blending process of different wheats to meet the desired flour attributes of their niche markets. In either case, millers produce flours which consist of characteristics that sufficiently allow the miller to retain its customers by creating the flour suitable to their needs. The desired course of action is to analyze the flours offered by millers to various markets where HWS is expected to enter. These flours will be analyzed in terms of the characteristics of the flour to determine the acceptance HWS in the flour blend. An estimate of demand for HWS can be determined by discovering the substitutability of HWS into these blends such that the flour quality specifications have been satisfied.

Each type of flour possesses various important characteristics, such as protein content, ash content, and gluten content. Depending on the end use application, some of these quality characteristics may be extremely important, while others may be of lesser importance for certain end products. The following chapter gives an account of the targeted end products of hard white wheat, as well as an account of the important flour characteristics and the typical flour specifications required to achieve the specified end product.

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[22] Samuel A. Matz *Ingredients for Bakers* (McAllen: Pan-Tech International, Inc., 1996).

1.6 Organization of the Study

Chapter 2 gives an account of the literature reviewed in consideration of the development of the thesis methodology. Various research methods and perspectives are identified and discussed, as well as consideration of comparable studies with implications for analysis of HWS.

Chapter 3 discusses the methodology chosen in the study to accomplish the analysis. It describes linear programming and how it is used in the study to achieve the desired results and describes the variables identified as being most appropriate for use in the model.

Chapters 4 to 9 deal with the linear programming results and filters out the resulting data in order to make meaningful implications as to the marketing potential of HWS. The results show expected shares of HWS acceptance in various flour blends, allowing for implications as to the market potential for HWS. As well, the results indicate the estimated price that HWS would expect to realize relative to other wheats for acceptance in flour blends.

Chapter 2 Literature Review

2.1 Introduction

The literature review looks at what determines wheat flour quality, specifically for the end uses most suited for hard white wheat. Studies that attempt to determine optimal flour quality characteristics for breads, noodles, and flat bread end products are also considered in the literature review. Chapter 2 explores some of the few documented analyses of end product flour specifications and/or wheat compositions for Asian noodle and Middle East flat breads.

As well, Chapter 2 considers economic approaches of determining the potential of HWS by way of its quality contributions to the products. Related linear programming models were also studied for consideration in the research.

2.2 Asian Noodle Markets

Noodles are a traditional staple of most South East Asian countries. Noodle consumption can be traced back as far as 5000 BC in China, and continues to be an indispensable part of the diet in South East Asia[23]. Handmade noodles have been the traditional type of noodle, but in the 1950's machine made noodles were introduced, which have increased the availability and variety of noodles. Recent years have brought forth the development of instant noodles, which have been growing in popularity because of their convenience. Instant noodles are quick and easy to prepare, and are especially popular in urban centers where consumers have higher incomes and less time for food preparation. With the

[23] Hou Guoquan, et al. "Asian Noodle Technology," American Institute of Baking Technical Bulletin, Volume 10, issue 12. December 1998.

growth in Asian economies, more urbanization and industrialization has occurred, which has been highly correlated to the increased popularity of instant noodles.

Flour blend quality characteristics for Asian noodles are difficult to find because of the variety of different noodle products available, but also due to the fact that noodle flour specifications have not been adequately documented. The First International Oriental Noodle Symposium held in 1993 at the Canadian International Grains Institute (CIGI) provided an insight to some of the preferred characteristics of noodle flour for different countries in the South East Asian region. Noodle specifications differ between products, and from country to country depending on taste and preferences. This results in different flour characteristics being more or less dominant in the flour blend, be it color, texture, or taste. Representatives from several South East Asian countries provided some of the key determinants of producing the preferred noodle flour, which would include the desired flour characteristics for their market. The following section will explore the demand for noodle products, and give an indication of some of the key requirements to making acceptable noodle flours for popular noodle types in each respective country. The following section examines presentations by participants of the CIGI noodle symposium representing the countries of Japan, China, Korea, and Malaysia, as well as other literature which contains an indication of noodle flour characteristics and noodle markets.

2.2.1 Japan[24]

Japan is potentially a very important market for sales of Canadian HWS. Wheat consumption in Japan is about 6.3 mmt, of which, approximately 85% is imported[25]. In terms of wheat flour usage, about 36.2% is used in breads, 35.9% in noodles, and 12.8% in confectionery products[26]. Japan is highly valued as an export market for Canadian wheat because in addition to their reputation as a consistent buyer, Japan tends to be less price sensitive when selecting which wheat to import. Contrary to many other Asian countries, Japan usually will pay a price premium for high quality wheat.

In terms of flour characteristics, Japanese-style noodles generally require a wheat flour with protein level between 8-9%, a starch level containing low levels of amylase, high viscosity, and an ash content below 0.4%. The flour must also have a brilliant white appearance. In general, Japanese millers have relied mainly on ASW to create flour with the desired qualities.

Japanese millers also manufacture flour capable of producing "Chinese-style" noodles. Characteristics of the wheat flour necessary to produce Chinese-style noodles are somewhat different than for the Japanese-style noodles, mainly in that it is a higher protein product with firmer texture. This flour should have a protein content between 10.0 - 11.5%, an ash content of about 0.5%, and display good color stability during the

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24 Susuma Nakazawa, *Japan's Noodle Industry*. (Canadian International Grains Institute, 1993).

25 Hamed Faridi and Jon M. Faubion, *Wheat End Uses Around the World* (St. Paul: American Association of Cereal Chemists, Inc., 1995).

26 *Ibid.*

course of production. Millers traditionally have favored a semi-hard wheat in manufacturing this type of flour. Historically, to produce this type of flour, millers in Japan have favored ASW, or hard wheats such as CWRS, APH, HRW in combination with ASW.

Table 2.1. Desired Flour Characteristics for Noodles in Japan

Noodle Type	Protein %	Ash %	Color	Wheat Used
Japanese	8.0-9.0	<0.4	v. white	ASW
Chinese	10.0-11.5	0.5	white	HRW + CWRS, APH, ASW

Source: First International Oriental Noodle Symposium. CIGI, 1993.

2.2.2 China

The large population of China (about 1.2 billion) represents an important potential market for exports of Canadian HWS. China typically imports about 126-144 mmt of wheat, on top of about 90 mmt domestic production. It is estimated that 50-60% of wheat flour is utilized by noodle consumption.[27]

Table 2.2 shows a list of noodle flour specifications for popular Chinese style noodles[28]. In general, high gluten flour is used to make most types of Chinese-style noodles. Mid-protein Flour #1 and Flour #2 are used to produce fine dried noodles, as well as instant fried noodles. On top of the listed characteristics, Chinese noodle flour requires good color stability. The desired color for Chinese noodles is a light yellow to milky white; these colors should not deteriorate throughout the entire noodle making process. In general, semi-hard wheat is used to produce the desired flour, utilizing HRW (11.5%), or HRW blended with CWRS, APH, or ASW.

Table 2.2. Desired Flour Characteristics for Popular Noodles in China

	Water (%)	Wet gluten (%)	Protein (%)	Ash (%)
high gluten flour #1 (non-fried instant, cold, thread)	14.5	>30.0	>12.2	<0.7
high gluten flour #2 (non-fried instant, cold, thread)	14.5	>30.0	>12.2	<0.85
flour #1 (fine dried)	13.5	>26.0	>10.6	<0.7
flour #2 (fine dried, instant fried)	13.5	>25.0	>10.2	<0.85
low gluten flour	14.0	>21.0	<10.0	<0.6

Source: First International Oriental Noodle Symposium. CIGI, 1993.

2.2.3 South Korea[29]

In South Korea, wheat is almost entirely imported, mainly from Canada, USA, and Australia. Wheat consumption in South Korea is about 1.8 mmt annually[30], of which 45% ends up in noodle production. South Korean flour production has shown steady increases in recent years; this includes flours processed for noodles. Instant noodles are gaining in popularity in South Korea and are a key source of the increase in noodle production. Key flour characteristics denoted in determining quality were protein content, ash content, flour color, and starch damage. Table 2.3 lists six types of end products and the blends typically used to achieve the desired flour characteristics.

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27 *Ibid.* Page 24

28 Liu Fu Chun, *Noodle Production in China.* (Canadian International Grains Institute. 1993).

29 Y.S. Kim, *Flour Milling & Noodle Industry in Korea.* (Canadian International Grains Institute. 1993).

30 *Faridi, Hamed, and Faubion, Jon M. Wheat End Uses Around the World. American Association of Cereal Chemists, Inc. St. Paul, MN, 1995.*

Table 2.3. Desired Flour Characteristics for Popular Noodles in Korea

	Wet	Fresh/Raw	Dried	Non-fried instant	Bag-type instant	Cup-type instant
Wheat blend	ASW (100)	DNS/WW/ASW (30/30/40)	HRW/WW (50/50)	DNS/ASW/HRW /WW (40/20/20/20)	DNS/HRW/WW (50/25/25)	ASW/HRW /WW (50/25/25)
Protein %	8.6	8.6	10.5	10.5 - 11.5	10.5 - 11.5	9.0 - 10.0
Ash %	0.38	0.38	0.4	0.42	0.42	0.42
Flour Color*	87.2	89	85	82	82	82
Starch Damage	<2%	<2%	<2%	<2%	<2%	<2%

*KATT C-100 used to determine flour color
Source: First International Oriental Noodle Symposium. CIGI, 1993.

Four important factors in determining flour quality have been identified for noodle production in South Korea. The factors which determine noodle quality and therefore flour acceptance are, in order,

1. Color and appearance
2. Protein content
3. Mechanical properties of uncooked noodles
4. Mechanical properties of cooked noodles
5. Textural stability after cooking

This ranking is consistent with most countries within South East Asia. In general, color is the most important factor in quality determination, with other characteristics such as protein, texture following in rank. South Korea has traditionally relied on low protein wheats such as WW from the U.S.A. and ASW from Australia as the main wheats used in noodle production.[31]

[31] *Faridi, Hamed, and Faubion, Jon M. Wheat End Uses Around the World. American Association of Cereal Chemists, Inc. St. Paul, MN, 1995.*

2.2.4 Malaysia[32]

Malaysia requires about 590,000-760,000 mt of wheat imports to satisfy its demand. It is estimated that about 45% of wheat flour is used for noodles[33]. Australian ASW has historically had a dominant share of Malaysian wheat imports, due to its suitable properties, but also due to Australia's proximity to the market. In Malaysia, noodles require unbleached flour of low ash content for bright color. Protein levels for popular noodles in Malaysia are typically between 9.0 - 13.5%, with the general tendency to increase protein content to achieve a firmer texture. Other requirements are a Falling Number greater than 300 seconds, low starch damage, and low enzyme activity. Generally, a medium to strong dough strength attribute is desired. These flours have historically been produced using CPSW/ASW with hard wheat as needed to increase protein levels. For high protein noodle such as wanton noodles, high protein flour with strong dough properties is required to make a suitable noodle. In this case, mainly higher protein wheats such as CWRS, Dark Northern Spring (DNS), and APH are used.

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[32] Oh, Siew Nam. Noodle Industry in Malaysia. First International Oriental Noodle Symposium. Canadian International Grains Institute. 1993.

[33] Hamed Faridi and Jon M. Faubion, *Wheat End Uses Around the World* (St. Paul: American Association of Cereal Chemists, Inc., 1995)..

Table 2.4. Desired Flour Characteristics for Popular Noodles in Malaysia

	Protein %	Ash %	Dough Properties
Wet	10.0 - 11.0	0.44 - 0.48	medium
Instant	10.5 - 11.5	0.44 - 0.48	medium
Dried	11.0 - 12.0	0.44 - 0.48	slightly strong
Raw (wanton)	12.5 - 13.5	0.48 - 0.52	very strong

Source: First International Oriental Noodle Symposium. CIGI, 1993.

2.2.5 Recommended Blends of Canadian Wheat for Asian Noodle End Products

The Canadian International Grains Institute has made an effort to formulate recommended blends of Canadian wheat which would effectively produce a flour which is composed of the desired characteristics needed to ensure satisfactory end products in the Asian noodle market[34]. Tables 2.5 through 2.7 give recommended blends of Canadian wheat to produce flours which would be suitable to create different types of common Oriental style noodles. Most common types of noodles are those where color, firm texture, and cooking yield are important. These noodles are common to all South East Asian countries. The recommended blends of Canadian wheat which result in these particular end products is indicated in Table 2.5 below. In most instances, CPSW would be used as a base wheat, holding a large share of the flour blend, and supplemented with other soft white or red wheat as necessary.

[34] Canadian International Grains Institute. *Grains and Oilseeds. Handling, Marketing,Processing* (Winnipeg: Canadian International Grains Institute, 1993).

Table 2.5. Composition of Wheat Flour for Noodles of Good Color, Firm Texture and High Cooking Yield

Noodle Type	CWSWS %	CPSW %	CWRW %
Handmade	-	80	20
Thin	30	30	40
Thick	40	20	40
Boiled Thick	25	40	35
Dried	50	20	30

Source: CIGI, Grains and Oilseeds (1993)

Table 2.6 provides six possible blends of Canadian wheat which would incorporate each wheat's inherent characteristics to achieve at a flour which is acceptable for production of noodles of good color, and firm, elastic texture. This description is quite broad but is consistent with the desired characteristics of most noodle types in the Asian marketplace. It is evident that for most flour, a significant level of white wheat is required in the flour, and blended with hard red wheat to produce the desired outcome. Table 2.7 describes preferred blend for Canadian wheats for noodles in which color is not major factor in the desired characteristics. In this situation, it is clear that hard red wheat plays a significant role in the flour blend. However, white wheat is often recommended in the blend to result in the desired flour.

Table 2.6. Composition of Wheat Flour for Noodles of Good Color, Firm and Elastic Texture

CWSWS %	CPSW %	CWRW %	CWRS %
20	30	20	30
-	30	30	40
20	45	-	35
50	-	-	50
-	80	-	20
-	-	100	-

Source: CIGI, Grains and Oilseeds (1993)

Table 2.7. Composition of Wheat Flour for Compound Noodles in which Carrying Strength, not Color, is Critical

Noodle Type	CPSR %	CWRW %	CWRS %
Buckwheat, Rye	-	-	100
Korean Lien Mien a)	-	50	50
Korean Lien Mien b)	50	-	50
Barley	-	40	60

Source: CIGI, Grains and Oilseeds (1993)

Table 2.8 serves as a guideline for suggested flour blends which are capable of producing suitable steamed and fried noodles, which are popular types of noodles in most regions of South East Asia. Listed are the major required attributes of the flour and the wheat blends which would sufficiently achieve these flour attributes. Again, it can be seen that hard red wheat, while suitable for noodles of high protein content, requires supplementation with mid-protein wheats and white wheats for low protein noodles.

Table 2.8. Wheat or Flour Blending Ratios for Steamed and Fried Noodles

		First Choice	Second Choice	Third Choice
Protein Content of Mill Grist %[1]		13.00 max	12.50 max	11.75 max
	Option 1	CWRS 100	CWRW 100	CWRW:CPSW 60 : 40
	Option 2	CWRS:CWRW 50 : 50	CWRS:CWRW:CPSW 20 : 50 : 30	CWRS:CPSW 20 : 80
	Option 3	CWRS:CWRW:SWS 50 : 30 : 20	CWRS:CPSW 40 : 60	CWRS:CPSW:SWS 30 : 50 : 20
Flour Extraction %[2]		70 max	80 max	90 max
Flour Ash Content %		0.38 max	0.42 max	0.48 max
Flour Protein Content %[3]		11.25 min	11.00 min	11.00 min

[1] As is moisture basis
[2] Based on straight-grade flour
[3] 13.5% moisture basis
Source: CIGI, Grains and Oilseeds (1993)

2.2.6 Summary – Asian Noodles

There are four main types of noodles consumed in Asian countries. These are, Instant noodles, Japanese high swelling starch noodles, white-salted noodles, and alkaline noodles. However, for the purpose of this study, it is assummed that all Asian style noodles can be grouped loosely into two types, Japanese-style noodles and Chinese-style noodles[35]. The Japanese noodles are white in color with soft texture and a lower protein content, and are typically composed of soft wheats. Chinese noodles are typically yellow and have a firmer texture attributed to the increased protein content, and are typically composed of hard wheats. For the purpose of the study, all Asian noodles will be grouped into these two large noodle groups and will serve as proxies for all types of Asian noodles.

[35] Gary Vocke, *Noodle End-Use Characteristics for Wheat in East and Southeast Asia,*(accessed 1998); available from http://usda.mannlib.cornell.edu/re…ld/whs-bby/wheat_yearbook_03.30.98; Internet..

2.3 Flat Bread Markets

According to Quail (1996), hard white wheat is the preferred wheat for flat bread production. The general recommendation for wheat suited to baking Middle Eastern (Arabic) flat bread is a "hard, white wheat, of moderate protein and free from weather damage"[36]. Flat bread production usually is associated with flours of high extraction rates and ash content. Qarooni et al (1992) state that the mean extraction rate for Arabic breads in the Middle East is 80%. Quail (1996) also suggests that for wheats with protein content at the upper end of the scale (such as most Canadian wheat exports), a high extraction rate would be desirable to produce optimal Arabic breads. From these descriptions, HWS would appear to be advantageous.

Quail (1996) states that for purchasing wheat in the Middle Eastern markets, price and quality are the key components. In terms of flour quality, the desired characteristics are protein content, starch damage (which has an impact on water absorption), and flour color, although other properties have implications on flour quality as well.

Qarooni et al (1998) found that the optimum flour protein content for Arabic bread was 10-12% while Quail et al (1991) found that flour with a protein content of 9-12% was suitable. Protein measures above and below these ranges reduces bread quality. More precisely, flours of protein content below 9% have insufficient water absorption capabilities making sheeting of the bread difficult, as well as causing a dry and brittle end

[36] Kenneth J. Quail *Arabic Bread Production* (St. Paul: American Association of Cereal Chemists, Inc., 1996).

product. Flours of protein content above 12% tended to result in doughs that were too strong, and sticky.

Protein quality relates to dough mixing characteristics like strength, elasticity, and extensibility. These qualities are measured by Farinograph and Extensigraph tests. Appropriate Farinograph development times for Arabic bread dough has been calculated by Quail et al (1991) to be between 2 and 5 minutes. Qarooni (1988) calculated optimum Farinograph development times of 3.5 to 4.5 minutes, while flours with development times of greater than 5 minutes tended to be too strong, and less than 2 minutes to be too weak. Farinograph stability times up to 8 minutes proved to show that the flour had good mixing tolerance, while it was advised that stability times under 3 minutes were inappropriate for flat breads. Extensigraph tests indicate the level of protein strength and extensibility. It has been concluded that good quality flat bread require maximum Extensigraph resistance of 250-350 Brabender Units (BU) and an extensibility of greater than 20 cm. Quail (1991) found that the greatest weakness with hard wheats studied was strong protein with poor extensibility.

Water absorption should be high for flat bread production, according to Quail et al (1991), with Farinograph absorption values ranging from 58-65%. Water absorption is correlated to the dough yield, as well as texture and quality of the end product. Qarooni (1988) concluded that water absorption should be no less than 60%, with no upper limit, although studies have shown that above 65%, doughs become difficult to handle. Because water absorption capabilities must be high, a hard type of wheat is well suited to meet this need. Hard wheats require more harsh milling procedures to refine the flour, this results in increased starch granule damage, which has a direct affect in water absorption. An increased level of starch damage increases the water absorption capability of the flour. Therefore, since hard wheats require harsher milling, it has been concluded that hard wheats are more suitable than soft wheats for this purpose. This is supported by a Quail et al. (1988) study that found grain hardness was significantly related to flat bread quality. Of course, starch damage is not the only contributor to water absorption. Gluten protein also contributes to water absorption; therefore, high protein wheats are more capable of increasing water absorption.

Flour for flat bread must be sound in nature and free from weather damage, as damaged or unsound wheat adversely affects flour quality and end product quality. Soundness is a measure of alpha amylase activity, and is measured by way of a Falling Number test. Williams and El-Haramein (1989) found that flour from wheat with greater than 5% weather damage were significantly inferior to that of flours with less than 5% weather damage. Optimal Falling Number results were found to be greater than 250 seconds.

Flour color is an important characteristic in flat bread products. Quail (1990) suggests that flour with a Kent-Jones color grade below -3.2 is required. White wheat is deemed to be the most appropriate wheat for flat bread because not only do red wheats have noticeably darker flour color at high extraction rates, they have also been associated with undesirable flavors.

Table 2.9 indicates the desired quality characteristics in wheat selected for the purpose creating flour intended for flat bread production. The important characteristics are protein content, hardness, color, and soundness.

Table 2.9. Quality Characteristics for Wheat Intended for Flat Bread

Quality Characteristics	Preferred for Arabic Bread
Hardness	Hard (PSI <20)
Color	White (especially for high extraction flours)
Protein Content	10-13%
Soundness	Sound (FN>250 sec)

Source: Quail (1996)

As described previously, flat bread flour quality depends of the attributes inherent in the milled wheat. Table 2.10 details the required flour characteristics needed to produce an optimal end product.

Table 2.10. Quality Characteristics for Flour Intended for Flat Bread

Quality Characteristic	Preferred for Arabic Bread
Protein Content	9-12%
Starch Damage	6-9%
Farinograph	
Water Absorption	58-65%
Development Time	2-5 minutes
Extensigraph	
Maximum Resistance	250-400 BU
Extensibility	18-25 cm
Color (Kent-Jones method)	<3.2

Source: Quail (1996)

Similarly, Qarooni (1988) conducted a study to determine flour characteristics preferred for Arabic flat bread and found the following desired levels for flat bread at Kuwaiti commercial flourmills. These results were compared with a similar study done by Maleki (1984) in Iran. The findings are shown in Table 2.11. Both tables reveal the optimal flour characteristics to make flat bread. The findings of the studies strongly correspond to each other, therefore a greater level of confidence can be put into the results.

Table 2.11. Characteristics of Flour for Arabic Bread Production

Characteristic	Commercial Kuwait Flour	Iranian Flour (reported by Maleki (1984))
Protein %	11.5	12.0
Ash %	1.0	1.6
Flour Extraction %	-	90
Farinograph water absorption %	63.0	64.4
Development time (min)	4.5	-
Valorimeter value	55	53
Extensigraph area (cm)	87	44
Maximum resistance (BU)	370	290
Extensibility (mm)	152	107

Source: Qarooni, 1988

2.3.1 Summary – Flat Breads

Based on the desired flour qualities needed to prepare flat breads, HWS would appear to be well suited for the purpose. Flat breads generally require hard wheats of relatively high protein, and a high extraction rate. The various studies discussed in this chapter seem to confirm that HWS may be ideal for flat bread production.

2.4 Methodology to Estimate Derived Demand for Wheats

In terms of economic applications to determine the demand for HWS, methods which incorporated analysis of characteristics to determine demand were considered. The required flour characteristics for various flour blends needed to produce a specific end product, whether it be loaf breads, noodles or flat bread, can be used to estimate the potential demand for and value of Canadian HWS. If flour millers do not think of the commodity (wheat) as the end product, but the characteristics inherent in the commodity, then models which make use of commodity characteristics can be specified in determining flour miller demand. Wheat in this context is an intermediate input in manufacturing flour. The milling attributes of the wheat provide its value in the context of the flour being milled.

2.4.1 Cost Minimization

Assuming that a flourmill wants to minimize its cost to manufacture a flour with certain end product characteristics, this process can be modeled to determine the demand for a new wheat. In this case, wheat is an input to the milling process which contains characteristics needed to produce a desired flour. A miller desires to minimize its cost by creating a flour blend which meets the quality requirements of a flour as demanded by the consumer. Linear programming (LP) is a widely used technique of economic modeling, to determine the blend of ingredients in a manufacturing process.

2.4.2 Linear Program

The following is an example of a methodology that makes use of duality theory in a linear programming blend problem to estimate values of characteristics. The theory assumes a cost minimizing firm,

$$\text{Min } p_j x_j$$

$$\text{S.T. } a_{ij}\, x_j \geq b_{i0},\ i = 1, 2, \ldots\ldots n$$
$$x_j \rangle\ 0,\ j = 1, 2, \ldots\ldots\ldots n$$
$$x_j = \text{unrestricted}$$

Where p_j = price of jth ingredient (e.g. price of 1CWRS 13.5%)

x_j = quantity of jth ingredient used per unit of output

a_{ij} = the quantity of the ith characteristic in one unit of the jth input (e.g. 13.7% protein in CWRS 13.5% wheat)

b_{i0} = the amount of the ith characteristic required in one unit of output (e.g. 10% protein for flat bread flour)

The dual to the problem is,

$$\text{Max } b_{i0} y_i$$
$$\text{S.T. } a_{ij} y_i \leq p_j$$
$$y_i \rangle\ 0$$
$$y_i \text{ unrestricted}$$

where y_i is the shadow price of the ith characteristic. McKeague (1992) states, "Duality theory indicates that the minimum value of the primal equals the maximum value of the dual thus Min $p_j x_j$ = Max $a_{i0} y_i$. Then if a_{i0} is changed by some amount Δa_{i0}, the primal minimization must change by the same amount. Then Δmin $p_j x_j / \Delta a_{i0}$ = max $a_{i0} y_i / \Delta a_{i0} = y_i$, where y_i is the shadow price of the ith characteristic. The shadow price measures both the effect on minimum total ingredient cost per unit of output of varying a_{i0} and also the effect on maximum monetary value of nutritional requirement of varying a_{i0}."

Discovering the value of characteristics by using a model such as this can aid in determining the potential demand and value of a new type of wheat based on its inherent characteristics.

2.5 Summary

The model considered in this chapter is useful in analyzing demand for products based on characteristics rather than on the product itself. This model is beneficial is assessing values for characteristics or for determining blends of wheat which would sufficiently meet its required flour characteristics. These values can be used to make estimations on the potential for Canadian HWS on entering the target markets of Asia and the Middle East, as well as the domestic market for pan breads. Of course, these applications could also be directed toward any market, so long as a set of required characteristics was available.

Chapter 3 Methodology

3.1. Linear Programming - Least Cost Flour Blend

Potential usage of hard white wheat can be assessed through determining the quantities of hard white wheat utilized by wheat importers. This is approached in terms of a derived demand for wheat. Millers provide their customers with flour acceptable for various end uses, with the specified characteristics. Flours are created from various blends of wheat to achieve a satisfactory formulation. In producing a blend which meets end use needs of a customer, a miller must also be concerned about cost if the flour market is competitive. The need for millers to achieve the specific blends at the lowest cost results in the derived demand for hard white wheat in terms of its characteristics relative to the attributes found in substitute wheats.

Different end products require the use of different flour blends to achieve the satisfactory end product. These blends differ between products and across borders. There are seemingly infinite number of blends needed to create the numerous end products. These flour blends must contain the characteristics required to successfully produce the end product. These characteristics must be kept within specifically identified ranges and are accomplished by a selected mixture of various wheats available to the miller. In this study, a suitable blend of wheats will be determined at the least cost to the miller to achieve the flour with the desired range of flour characteristics. This will be accomplished by specifying an LP model to determine the least cost flour blend, which meets the quality constituents of a particular blend.

The model used is based on a linear program developed for the Canadian International Grains Institute (CIGI). Similar models are used extensively in the feed milling industry, where feed rations are formulated based on the least-cost ration composed of ingredients which allow for the specified nutrient composition. In the same fashion, a least-cost grist can theoretically be formulated for the flour milling industry, which calculates the optimal blend of flour streams depending on the desired flour end use characteristics. These characteristics include protein content, extraction percentage, and absorption capability, among others.

Quality characteristics have to be additive in nature before being accepted into the model; therefore some potentially interesting variables were forced to be omitted. Moore, Lee, and Taylor describe linearity in this fashion:

"The term linear implies that relationships are directly proportional. Proportionality means that the rate of change, or slope, of the functional relationship is *constant*, and therefore changes of equal size in the value of a decision variable will result in exactly the same *relative* change in the functional value"[37].

As an example, if two flours were blended, flour A at 14% protein, flour B at 13% protein, and if these were blended at 50% each, the resulting flour blend C should be 13.5% protein if the protein variable is linear. This is a key requirement of linear programming, thereby excluding some quality variables not conforming to linearity. In the study, flour quality characteristics such as protein content, wet gluten content, extraction rate, liquefaction number, Farinograph absorption, Farinograph stability, and

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[37] L.J. Moore, S. M. Lee and B. W. Taylor, *Management Science,* (Boston: Allyn and Bacon, 1993).

flour color were identified as some of the key linear characteristics. The model was specified and run on Excel Solver to achieve the solutions.

The linear program follows the objective function:

$$\text{Min } Z = \Sigma\, c_i x_i$$

$$\text{Subject to } a_{ij} x_i \leq \geq b_j$$

Where Z = total cost
c_i = cost of flour from wheat i
x_i = amount of flour i processed
a_{ij} = amount of characteristic j found in wheat i
b_j = level of characteristic required in the flour blend
i = 1-13
j = 1-5

Different flour blends were analyzed according to their potential suitability for HWS usage. For the domestic market, where high volume pan breads dominate the market, a "domestic pan bread" flour blend was analyzed. This blend is common to large domestic industrial bakers, and therefore will serve as a determinant for the suitability of HWS in the domestic bread market.

The second blend analyzed was a "specialty flour", which typically is a more specialized baker producing products with stronger gluten requirements and higher protein requirements. This product includes such items as hamburger buns, rolls, and other higher protein goods. This blend, as well as the pan bread situation, comprise the blends chosen to represent the domestic market, and give the result of the appropriateness of HWS in domestic blends.

Analysis of the potential for HWS in target export markets was achieved by analysis of the possible acceptance of HWS in flour blends suitable for producing oriental noodles and Middle East flat breads, since these are the products seen to be most suited to HWS use. A high extraction flat bread flour was used to determine HWS acceptance into the Middle East. This flour is common and widely used in most Middle East countries as well as the Indian Subcontinent. Two types of noodle flour were considered to determine HWS demand in South East Asia, a flour suitable for making Chinese style noodles, and a flour suitable for making Japanese style noodles. The Japanese noodle differs mostly from the Chinese noodle in that it has a lower protein content and softer texture. As discussed in Chapter 2, there are numerous types of noodles consumed across the Asia-Pacific region, however, a 1998 USDA article[38] states that "Oriental noodles can be divided broadly into white, Japanese-style noodles and yellow, Chinese noodles", therefore these two noodles provide a good approximation of the entire Asian-Pacific noodle market.

3.2 Determination of the Cost of Flour for Various Wheats

The first order of duty in the analysis is to determine the actual cost of a tonne of flour produced from each wheat, which can vary quite substantially from the actual cost of the wheat. Two wheats priced identically may have significantly different costs per tonne of flour produced from them depending on inherent, and growing condition related, quality factors. To determine the value of flour produced from a tonne of wheat, the milling

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[38] Gary Vocke, *Noodle End-Use Characteristics for Wheat in East and Southeast Asia*, (accessed 1998); available from http;//usda.mannlib.cornell.edu/re…ld/whs-bby/wheat_yearbook_03.30.98; Internet..

process must be simulated. Each type of wheat is therefore subjected to a "virtual" milling process to determine the yield of flour and the derived cost of that flour.

First, the actual wheat tonnage is reduced due to foreign material such as other grain, weed seed, stones, and dust, which cannot be used in the flour making process. Some wheat has higher allowable foreign material content than others (e.g. 1CWRS vs. 3CWRS), the maximum allowable foreign material content is assumed where it is not specified. This gives us a measure of clean wheat ready for further processing.

Secondly, water is added to the wheat in what is called the tempering process. Different types of wheat are generally milled at a standard moisture content. Table 3.1 illustrates the general standards used to achieve the optimal milling conditions by the milling industry.

Table 3.1. Standard Milling Moisture for Wheat

Wheat	Optimal Milling Moisture
Hard wheat	16.0%
Semi-hard wheat	15.5%
Soft wheat	14.0%

Source: Ashok Sarkar (Head, Milling Technology – CIGI)

The difference between the optimal milling moisture content and the natural moisture content of the wheat gives the allowable percentage of water able to be added by the miller. For many flour mills water is essentially free, therefore, it is to the miller's benefit to have the driest wheat possible, thereby increasing the tonnage of the grain with a low cost input. It is alleged that Canadian wheat is often discounted compared to

Australian wheat in international markets for this reason. Canadian wheat (about 13.5% moisture) is harvested at a higher natural moisture content than Australian wheat (about 11% moisture). From this method it is possible to calculate the measure of clean and tempered wheat.

As mills are kept very dry, there is an inevitable milling loss in every operation through evaporation and through general processing. This loss is assumed to be 0.15% in the study and is deducted from the clean and tempered wheat.

Each wheat's historical average extraction rate is now incorporated into the calculation. The extraction rate multiplied by the clean and tempered wheat tonnage determines the amount of flour generated by the particular type of wheat.

The amount of product left after flour extraction is completed is considered millfeed. Millfeed is used primarily as livestock feed, and therefore has some value. The millfeed is assumed to be valued at US$100/mtonne in this study. The value of the millfeed is subtracted from the cost of the wheat because this amount is returned to the miller. The cost of wheat minus the value of millfeed returns the cost of flour. This allows us to calculate the value of flour per tonne of wheat ground.

Finally, the cost per tonne of flour is determined by dividing the cost of flour per tonne of wheat by the tonnage of flour yielded. This process is applied to each individual type of wheat for usage in the linear program.

Least-cost flour formulations were performed using various types of wheats, selected to serve as a representative sample of wheats from exporting countries. For Canada, the representative wheats are 1CWRS 13.5%, 2CWRS 12.5%, 3CWRS, and CPSW. Also, a high quality HRS was included for Canada, as well as a lower quality HRS, recognizing that for every harvest, a percentage will be downgraded to lower grades. For the U.S.A, the representative wheats are Dark Nothern Spring (1DNS) 14%, Hard Winter Ordinary (HWO), and Western White (WW). For Australia, the representative wheats are APH, and ASW. Two other lower quality wheats present on the global market are also included, namely Trigo Pan from Argentina, and EU soft wheat from Europe However, only Canadian and US wheats were used in the analysis of the domestic market. No Australian, EU or Argentine wheat was included in the available wheats to the model as this was not considered a realistic market situation. For consistency of pricing, all prices were FOB at the Pacific Coast.[39]

For analyzing the export market, wheats from all exporting countries were included in the model. Pricing for each type of wheat was FOB port plus a 5-year average freight factor[40] for wheat from origin to export destination in order to determine the landed cost of the wheat.

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[39] International Grains Council, *World Wheat Statistics* (London: International Grains Council).
[40] *Ibid.*

3.3 Ash Correction Factor

Ash content is a measure that is often specifically stipulated by buyers of wheat and flour. Ash content in flour is a measure of the refinement of the flour. The endosperm of the wheat (where the finest flour is extracted) is low in ash content, while the outer bran which is separated the initial milling process but reprocessed for higher flour extraction, is much higher in ash content. Therefore ash content is a measure of extraction and processing of wheat; which physically manifests itself in the fineness and color of the flour.

All wheats analyzed in the study had their extraction rates adjusted to meet a standard ash content level for the specified end-usage. This was accomplished by the "ash correction factor". The ash correction factor governs the level of extraction calculated for each type of wheat. For small intervals around 75% extraction, the ash correction factor states that, on average, a 0.4% increase in extraction rate corresponds to a 0.01% increase in ash content[41]. Therefore to begin the simulation, all types of wheat are adjusted to achieve the same ash content, therefore, allowing for an adjustment in extraction rates. For example, in the domestic pan bread situation, the maximum allowable ash content is 0.5%. All wheat flour is therefore brought to a level playing field of 0.5% ash content, resulting in "adjusted extraction rates" for the wheat depending on the original ash content of the wheat. For example, DNS flour having a natural level of ash at 0.44% and an extraction rate of 68.5% will have an adjusted extraction rate of 70.9% to correspond to the increase in ash content to the 0.5% standard. The extraction rate will vary

[41] Ashok Sarkar, Head, Milling Technology CIGI *(Interview* 1998).

considerably according to the desired ash content of the flour. For example, flour used in production of high volume breads might have a maximum allowable ash content of 0.5%, while flat bread flour has a maximum allowed ash content of 1.0% making it necessary for the wheat to achieve a much higher extraction rate than for pan bread flour.

3.4 Linear Quality Measures Included in the Model

A 10-year historical record of wheat quality characteristics was compiled for each type of wheat. Data for these measures come from a various crop quality reporting agencies, inlcuding the Grain Research Lab of the CGC, Australian Wheat Board (AWB) crop reports, and US Wheat Associates For usage in the model, an average of each characteristic was used as a representative measure for the type of wheat[42]. Quality characteristics which where chosen for the model were based not only on their linear nature, but for their usage in terms of wheat selection. The following flour characteristics chosen for application in the model are quality characteristics often specified when buying wheat. There are other flour and wheat quality characteristics which are linear in nature, however, are not often specified by the industry, and therefore were not used in the model.

3.4.1 Protein Content

Protein is the most important quality characteristic in wheat flour. There are two measures of protein in wheat, quantity and quality. While quantity is fairly easy to determine, quality is not. The measure of protein quantity is used in this study due to its

[42] Wheat characteristics not published are estimated by expert opinion.

ease of determination. It may also be used as a proxy for protein quality. In any case, high protein quantity wheat is typically assumed to be high quality wheat. The protein present in a sample is the result of two factors; (1) the genetic or hereditary traits bred into varieties of wheat by plant breeders, and (2) the environmental conditions under which the crop was grown. Therefore, depending on the genetic makeup of the wheat, and the weather conditions under which it was grown, protein content will reflect a varying degree of consistency. Even with genetic manipulation to give a consistent protein level, weather plays a major factor in the final protein content and quality of the wheat.

Wet gluten content is another linear variable considered for the study. Gluten is an integral part to the functional properties of flour as it is the strength-giving component. It allows for dough to be held together and assisting in trapping carbon dioxide during baking, thereby allowing bread to rise. However, protein content and gluten content are highly correlated, therefore, only one of these two variables are needed. Protein content being the most commonly specified variable, is used in the study. However, it can be assumed also that protein content and gluten content are highly interchangeable.

3.4.2 Farinograph Absorption

Farinograph absorption is a linear characteristic that indicates the amount of water able to be held by the particular flour. Water absorption is related to starch damage. Starch damage increases the water retaining capabilities of the flour. Increased water retention is important to bakers as water can be added to the dough to increase its weight and volume. Water is a low cost input to the baker, therefore a high water content increases the profitability of the final product. Absorption is measured as a percentage of the flour weight.

3.4.3 Liquefaction Number

Falling Number (FN) is a measure of damage to the wheat seed by evaluation of the alpha amylase activity in the grain. Alpha amylase activity is characterized by the converting of starch energy to sugar energy by the grain for use in germination. Therefore it is a measure of sprout damage in the seed. Sprout damaged wheat typically contains a high level of alpha amylase activity, and therefore is downgraded due to poorer quality. The use of flour from germinated wheat may results in small loaf volume in breads, and grey color in noodles. A sound sample of wheat is distinguished from damaged wheat by a high FN. While falling number appears to be an important variable, it is not linear in nature. Fortunately, another little used measure related to FN, called Liquefaction Number (LN). Liquefaction Number has linear properties and therefore may be used in the linear model. The equation to calculate Liquefaction Number is: 6000/(FN – 50). Therefore, a low LN (indicating low sprouting damage) is preferred to a high LN. This variable is especially important in this particular study since white wheats have traditionally been prone to pre-harvest sprout damage.

3.4.4 Extraction Rate (%)

Extraction rate is an important variable when dealing with wheat sales to Middle Eastern countries where high extraction rates are required for production of flat breads and chapattis. High extraction rates are the most important variable considered when wheat selection is made by buyers in this market. For this reason, white wheat has an inherent advantage over red wheat in these markets. Extraction was included as a variable only in the analysis of flat breads in the study since this quality characteristic is regularly specified for this application. Extraction requirements are not often specified in domestic application, nor for Asian noodle application. Even though extraction rate is a wheat characteristic and not a flour characteristic, it was deemed as valuable to the study and therefore included.

3.4.5 Farinograph Stability

Farinograph stability is defined as the resistance to breakdown during the dough making process, and is measured by the Brabender Farinograph. Stability is measured in terms of minutes and is a measure of mixing tolerance. Some types of wheat have weaker stability capabilities and tend to lose their structural integrity with prolonged mechanical processing. Higher protein wheats tend to have stronger dough properties and consequently have a higher mixing tolerance and greater stability. Stability may be a concern in end products, depending on the level of "toughness" desired in the product.

3.4.6 Flour Color

Flour color is an important variable contributing to visual appeal in the domestic market, but especially in foreign markets. The brightness of the flour is determined mainly by the color of the seed coat and the levels of extraction the wheat undergoes. Increased extraction levels result in decreased flour brightness, especially in red wheat. Flour color is a variable of greater importance in noodle and flat bread products than in the domestic bread market, and for this reason, the color variable was only incorporated in the export market analysis of this study. There are various measures of flour color. One of the more common measurements is the Kent-Jones flour color measurement. The anti-log of the Kent-Jones flour color test is said to be fairly linear, but was not used in the study as quality tests using this measure are not well documented across all types of wheat used in the study. Other measurements such as Minolta flour color tests are improved color measurements but are still fairly new and hence not common to all wheat tested.

The method of color determination used in the study was reflectance as measured by spectrophotometry. This data was found using Japanese import quality data as published by the Japan Wheat Research Association[43]. This method was selected for usage because color tests are not commonly performed with consistency between countries, and therefore there is difficulty in finding comparable results. The results from the Japanese import tests are directly comparable since they were performed with a common testing method. Reflectance data is also approximately linear in nature, therefore suitable for usage in the model.

Table 3.2 indicates the average flour characteristic values from 1987-1997 which were included in the model.

[43] Japan Wheat Research Association, *Tables for the Quality Survey of Imported Wheat Cargoes.*

Table 3.2 **Average Wheat Flour Characteristics (1987-1997)**

	Protein %	Extraction %	Wet Gluten %	Absorption %	LN	Stability (min)	Color
1CWRS 13.5%	13.17	75.63	38.99	65.52	17.56	9.29	79.86
2CWRS 12.5%	12.14	75.43	35.06	62.65	18.67	7.81	79.86
3CWRS	12.39	74.80	35.92	65.00	24.12	7.18	79.86
CPSW	9.84	76.30	28.54	59.58	18.73	3.60	80.27
1DNS 14%	13.16	72.46	35.94	64.95	17.89	10.93	79.09
HWOrd	10.96	74.08	28.04	60.58	17.60	6.88	79.60
WW	8.73	75.20	19.90	52.71	20.07	3.20	80.27
ASW	8.92	75.05	23.34	59.49	16.58	7.40	81.29
APH	12.94	75.53	36.12	62.70	14.97	12.59	80.09
Trigo Pan	10.16	67.00	33.45	59.62	19.71	8.15	79.60
EU Soft	9.80	70.20	29.00	54.93	24.93	4.50	80.27
HWS- HQ	13.17	75.63	35.92	65.48	24.12	9.29	80.09
HWS- LQ	12.14	75.43	35.92	62.65	24.12	7.18	80.09

Sources: Grain Research Lab, CGC
AWB Crop Reports
North Dakota Wheat Commission
Kansas Wheat Quality Reports
US Wheat Associates
Japan Wheat Research Association
Institut Technique des Céréales et des Fourrages
CWB, Market Analysis

3.5 Quality Constraints in Flour Blends

The flour quality characteristic ranges required by the various blends analyzed were determined mainly by way of various scientific studies and publications which identified optimal levels, and through expert opinion by Mr. Ashok Sarkar of the Canadian International Grains Institute who has extensive experience and expertise in this area.

Table 3.3 indicates the quality constraints entered into the linear program to arrive at the final results. Both domestic flour blends were analyzed at an ash level of 0.49%, the flat bread flour at 0.85%, Japanese-style noodle flours at 0.40%, and Chinese-style noodles at 0.50%.

Table 3.3. Flour Specifications Used in the Model

	Pan Bread Flour	Specialty Flour	Japanese Noodle	Chinese Noodle	Flat Bread Flour
Protein %	12.0 – 12.6	13.0 – 14.5	9.0-10.5	10.5 – 12.0	10.5 – 12.0
Extraction %	0				>=88
Absorption %	60-69	>= 64.5	57.0-62.0		58.0-65.0
Liquefaction Number	< 24	< 21	<=25	<= 25	<=30
Stability (min)	7.5-12	9.0-12.0	9.25-15.0	10.0 – 15.0	8.0 – 12.0
Color (reflectance)			80	79.5	79.5
Max 3CWRS %	15	15			
Max red wheat %					0

Sources: as per References, p. 113-116

3.6 Other constraints

3.6.1 Maximum Allowable Red Wheat

White wheat is a *requirement* for the production of certain end products. This is seen in end products like flat breads which require high levels of extraction and generally high ash contents while maintaining a bright white color. This is the case in the Middle East Gulf countries and the Indian subcontinent. Red wheats are typically not considered for selection in these countries; allowing for selection of red wheats in the model, therefore, would not provide a realistic situation. Therefore, zero tolerance for red wheat becomes a constraint in the model and red wheats are not allowed to enter into selection. The reason for zero red wheat tolerance has its origin in the fact that Middle East flat breads require extremely high quantities of bran using high extraction flour called "atta" and "roti". Red wheats have particularly dark flour color with high extraction and thus, do not have the visual appeal necessary for the end user. Millers in these regions will not even consider including red wheats in their blend because they are confident that they will not be able to sell their flour with any red wheat included. Wheat is generally composed of 83% endosperm, 14% bran, and 3% germ. Extraction rates in Middle Eastern Gulf countries are often around 88%, hence, the bright endosperm flour is entirely processed and a significant portion of bran is included in the flour as well. Considering this, it is not difficult to imagine the visual difference between a high extraction flour of dark bran origin compared with one of white bran color. Traditional wheat milling practices have included grinding wheat at extraction rates of up to 93%. This type of flour is still popular in these areas, therefore it is imperative that wheat be of white varieties. The refusal of consumers to tolerate red wheat in flat bread flour is documented in a 1997 Indian Express newspaper article which stated "the reason for declining the Argentinean and Canadian wheat preferred by the two Governments is the resolute consumer refusal to eat "red atta"[44].

3.6.2 Maximum allowable 3CWRS

A maximum allowable amount of 3CWRS was included as a constraint in the domestic bread flours, as millers will typically not exceed this level of 3CWRS due to wide variations in quality of this wheat, resulting in a more inconsistent flour product. The maximum allowable level is set at 20% as identified by McKeague (1992)[45]. McKeague's interviews with domestic millers indicated that "the consensus was that 10 to 20 percent of the wheat used in pan bread flour could be No.3 CWRS."

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[44] Swati Chaturvedi. "Foreign Wheat Worth Lakhs Lying in Indian Ports." *Indian Express*, 17 September 1997.

[45] Dale V. McKeague, "Competitiveness of CWRS Wheats in World Markets: Relevance of the Canadian Wheat Grading System with Respect to End Use Products." (Ph..D diss., The University of Manitoba, 1992) 175 .

3.7 Limitations of the Model

There is a small number of limitations and assumptions of the model worth mentioning. The first is that all variables must be linear in nature. Other flour characteristics of interest were not included for consideration in the model due to their non-linearity. Another factor is that some quality tests are not standardized between countries and are therefore not directly comparable, however, all wheat and flour quality tests were done using standard methods prescribed by the American Association of Cereal Chemists (AACC), and International Association of Cereal Science (ICC).

Canadian wheat tests are performed by the Grain Research Laboratory (GRL) of the Canadian Grain Commission (CGC). Test results are published in annual Crop Quality Reports. Australian wheat tests are performed by the Academy of Grain Testing (AGT). Australian test results for each type of grain are listed in annual AWB Crop Reports. The American test results for HRS wheat, grown in the northern states of Minnesota, Montana, North and South Dakota, are published by North Dakota State University.
Kansas Wheat Commission test results were used as a proxy for US HRW results. This is a good approximation since the majority of HRW is grown in Kansas. French wheat data is published by Le Institute des Céréales et des Fourrages and used as a proxy for EU wheat.

One of the limitations of the model in terms of wheat prices is that CWB wheat prices are not published. The CWB publishes asking prices rather than actual selling prices. For the study, International Grains Council (IGC) world wheat statistics were used throughout the analysis.

As Canadian grown HWS is not yet produced on a large scale, wheat quality data is not yet available. Therefore some assumptions have to be made regarding its expected quality measures. Since HWS is being developed from parent strains of CWRS, the model assumes that HWS quality characteristics are comparable to that of CWRS, with some exceptions. Harvest data of new HWS lines has shown that the natural ash content of HRS is lower than that of CWRS. This has an effect on the "adjusted extraction rate" applied to HRS in the model. That is, while test results on HWS have not shown HWS to have a pure extraction advantage over CWRS, because the model adjusts extraction rates to meet a standard ash content for the end product, HWS "adjusted extraction rates" show approximately a 2.5% yield advantage over CWRS. Another assumption is that of flour color. HWS was given flour color results equivalent to that of other high quality hard white wheats, namely APH. The third assumption was that of sprouting damage. For the study, HWS is assigned a measure of sprouting damage equal to that of lower quality white wheats grown in Canada, namely CPSW. This measure however, is not expected to be true on average for HWS, but would represent a worst-case scenario, as enhanced breeding is expected to eliminate this concern.

3.8 Products of Linear Programming

3.8.1 Measure of Substitution or Complementation

A least-cost LP gives an indication of the rate of substitution/complementation of HRS with others wheats, based on their combined contributions to the specified flour. The rate of substitution can be approximated by allowing for the blends to be simulated with and without HWS available. Parametrically adjusting the price of HWS allows for HWS share in the blend to increase or decrease according to its relative price and characteristics relative to other wheats. The extent that HWS enters the blend gives an approximation of its substitutability for the other wheats. Complementation of HWS may be seen if the inclusion of HWS increases the amount desired for another wheat.

The LP therfore, demonstrates the theoretical ability of HWS to compete with other wheats in both domestic and foreign end products. This is important in order to identify the extent that HWS could potentially compete with wheats of other origins in export markets, as well as in order to determine the potential acceptance of HWS in the domestic flour market. Hard white spring wheat, if accepted into the market, will compete with red wheats such as CWRS for market share.

3.8.2 Sensitivity Analysis

Linear programming is a valuable methodology in determining the extent of HWS acceptance into various flour blends. Sensitivity analysis performed by the LP allows identification of which constraints are binding, as well as for identification of shadow prices. Shadow prices for the cost of each flour stream in the blend identify which flours are not included in the blend, and also identify the dollar amount per tonne each particular wheat would have to change in order for it to be included in the blend or change from its current level. The slack and surplus values imputed to the quality characteristics identify the constraints which effectively determine the composition of flour in the blend. These measures help to determine the reasons why a wheat was included or not included in the blend, based on its characteristics. The shadow prices for the characteristic constraints identify which constraints are binding, as well as the amount by which the final cost of the blend could have been reduced given a one unit relaxation of the constraint.

Chapter 4 Results of Pan Bread Analysis

4.1 Introduction

Since the pricing and utilization of HWS depends closely upon the relative prices of alternative wheats, three market settings are used to evaluate the demand for HWS. The environments represent the largest, smallest and average price differential between high quality and lower quality wheats. The range of prices analyzed for substitute wheats represents the competitive setting that HWS would have encountered between 1980/81 and 1997/98. High quality HRS is initally priced at the level of 1CWRS 13.5%, and lower quality HWS is priced equivalent to HWO.

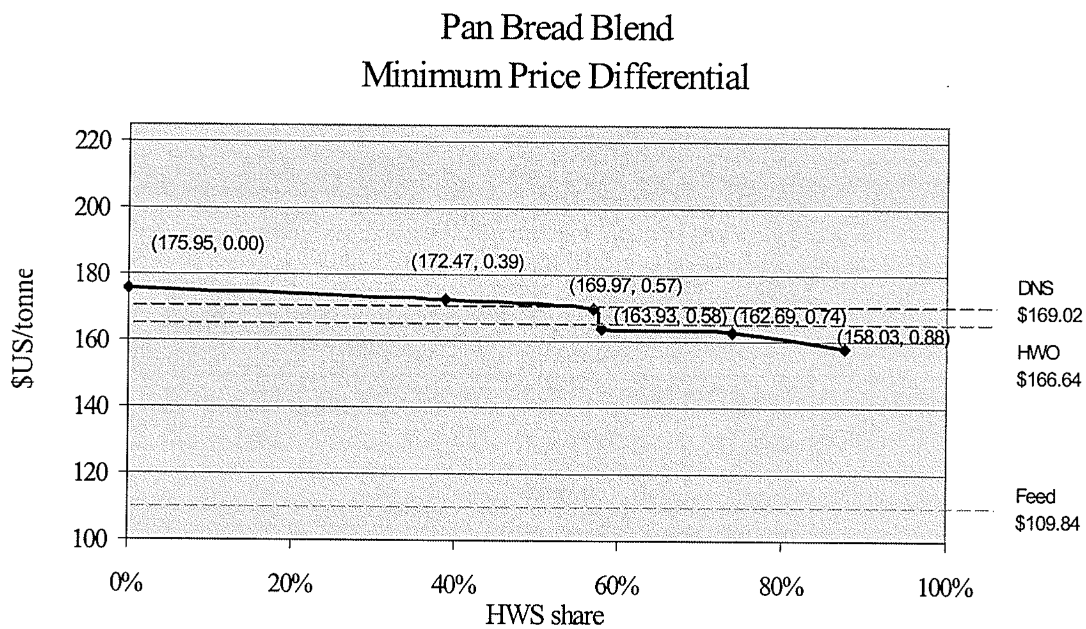
4.1.1 Minimum Price Spread between Low and High Quality Wheats

Applying a typical price structure for wheat when the premium paid for high quality wheat is at its lowest historical level, the following results were found. High quality wheat (DNS) is priced at US$169.02/mt with a discount of US$4.38/mt for lower quality wheats (Hard Winter Ordinary, HWO). Under this price structure, when HWS is priced equivalent to that of 1CWRS 13.5% at US $175.95/mt, it is not included in the flour blend. The dominant wheat in the flour blend in this scenario is 1DNS 14% which constituted 45.7% share of the blend. Lower quality wheat also entered the blend with 3CWRS usage maximized at 20.0%, while CPSW, WW, and low quality HWS also enter the blend.

Applying parametric price decreases to HWS indicates that HWS acceptance in the pan bread flour blend could increase significantly by a small reduction in price relative to other high quality wheats. HWS enters the blend at price of US$ 172.47/mt, which is at a price premium of US$3.45/mt to the market price for high quality red wheat (indicated by the price for 1DNS 14%), and comprises a 38.8% share of the flour blend. HRS substitutes directly with DNS when entering the blend. HWS usage in the blend increases to 57.0% with a further decrease in the price of HWS of US$2.50/mt. 1DNS 14% is forced out of the blend at this point and is fully substituted by HWS. At this point, HWS is at US$169.97/mt, and is at a US$0.95/mt premium to DNS.

Interestingly, further modest reductions in HWS price increase HWS acceptance, as it begins to substitute for lower quality wheats. HWS is maximized at 87.5% of the blend with WW satisfying the remainder of the flour characteristic requirements. At this price however, HWS is at a price discount to DNS of US$10.99/mt and at a discount to HWO of US$8.61/mt. Given price equivalency to DNS, HWS would approximately make up 57.0% of the flour blend.

Figure 4.1



Protein and Farinograph stability are the chief flour characteristics which determine the composition of wheats in this situation. This indicates that the final cost of the flour blend could have been lowered had the minimum protein content and stability level not been so limiting. In other words, lower quality wheats with weak protein and gluten strength would have been able to enter the blend given more relaxed constraints.

4.1.2 Implications

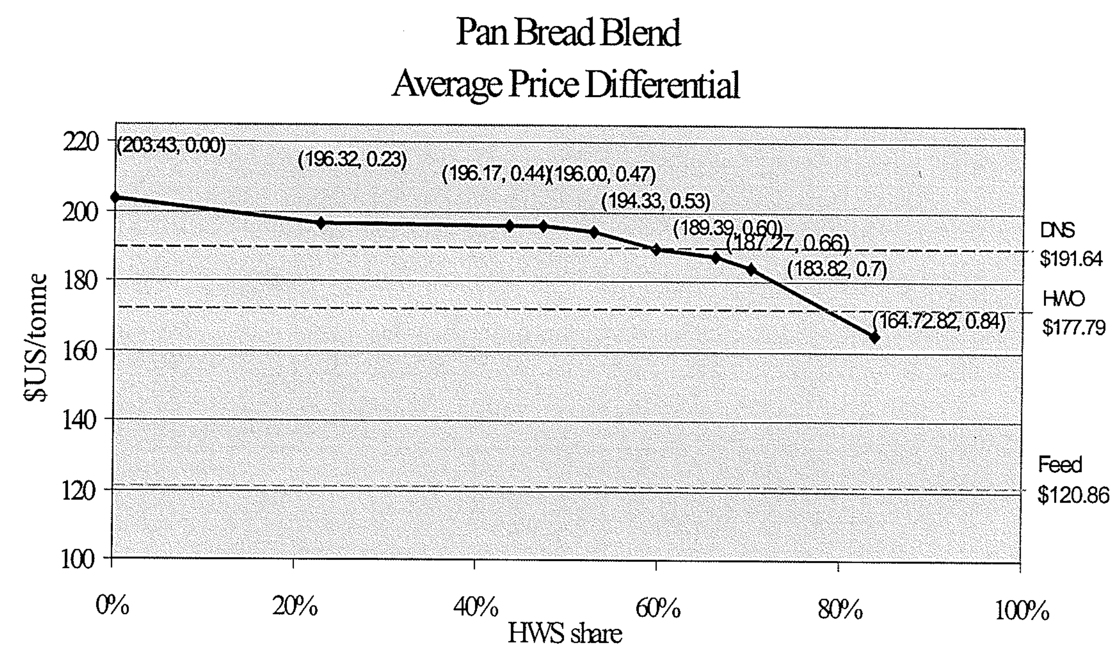
When low premiums exist for high quality wheats, high quality wheat can be substituted for lower quality wheats relatively less expensively than when premiums are high. Therefore, HWS will first force out other high quality wheats at prices around that of other high quality wheats. Then given slight price discounts, HWS will substitute for lower quality wheats. In the same fashion, HWS would be easily replaced by other high quality wheats when modest premiums for HWS are sought.

4.1.3 Average Price Spread between Low and High Quality Wheats

To represent the typical base market conditions, the average protein premium in terms of the price differential between high quality and low quality wheats was applied to the pan bread flour model. In this market scenario, DNS was US$191.64/tonne, and HWO was US$177.79/tonne, representing the typical price spread of US$13.85/mt. The price that HWS was set at in the first simulation was US$203.43/mt, the price of 1CWRS 13.5%, and at this price, it does not become part of the flour blend. For this price scenario, the preferred wheats in the flour blend are 1DNS 14% at 33.9% share of the blend, and HWO which made up 16.1%. Less costly, lower quality wheat, made up the remainder of the blend with 3CWRS, CPSW and lower quality HWS satisfying the remainder of the blend.

When all others prices are held constant, it can be demonstrated that the acceptance of HWS in the blend could increase significantly by a small decrease in its price relative to other high quality wheats. HWS first enters the blend at price of US$196.32/mt, at which point it composes 22.6% of the blend, and is at a premium to DNS of US$4.68/mt.. Again, DNS is noticeably replaced by HWS, suggesting that these wheats are the closest substitutes. Further price reductions allow for the substitution of the remaining DNS, as well as 3CWRS and HWO in the blend. The model shows that HWS would maintain a 52.8% share of the pan bread flour blend at price premium to DNS of US$2.69/mt. At price equivalency with DNS, HWS constitutes approximately 56% of the blend. HWS reaches a maximum content of 83.8% of the flour blend, however, at this level it is at a price discount to high quality red wheat of US$26.92/mt. As HWS usage increases in the blend, higher quality wheats are the first to be substituted, while the remainder of the flour quality characteristics are satisfied with small quantities of various low quality wheats such as WW and CPSW.

Figure 4.2



Protein content and Farinograph stability requirements were the main flour quality characteristics that determined the optimal blend of wheats. Stability levels only became restrictive at the point where HWS began to substitute for increasing amounts of high quality wheat in the blend, allowing more lower quality wheat to enter. When further substitution for the lower quality wheats occurred, stability was no longer an issue. Overall costs could have been lowered for the flour blend by using more lower quality wheat, however, the relatively protein content and stability requirements reduced their share of the wheat used. Lower quality wheats with weak gluten strength and lower stability levels may have been able to enter the blend at higher levels had the constraints been less demanding.

Tight specifications for large-scale pan bread production is characteristic of the industry. The tight specifications are required for the production of consistent quality breads, and reduction in the amount of re-calibrating of machines. This has a large impact on the optimal blend of wheats.

4.1.4 Implications

In the typical market price situation, HWS competes closely with other high quality wheats. Assuming DNS as the price indicator for high quality red wheat, HWS could achieve a maximum premium over similar high quality wheat of US$2.69/mt and achieve a majority share of the blend, as indicated by the model. A price premium greater than US$4.68/mt would effectively exclude HWS from the flour blend in favor of other high quality wheats. According to results of the model, at an equivalent price with other high quality wheat, HWS would expect to displace them and have about 56% share of the flour blend. This demonstrates that in the typical market situation, HWS would be a close competitor with other high quality red wheats, capable of attaining large shares of the market while also achieving a modest price premium.

4.1.5 Maximum Price Spread between Low and High Quality Wheats

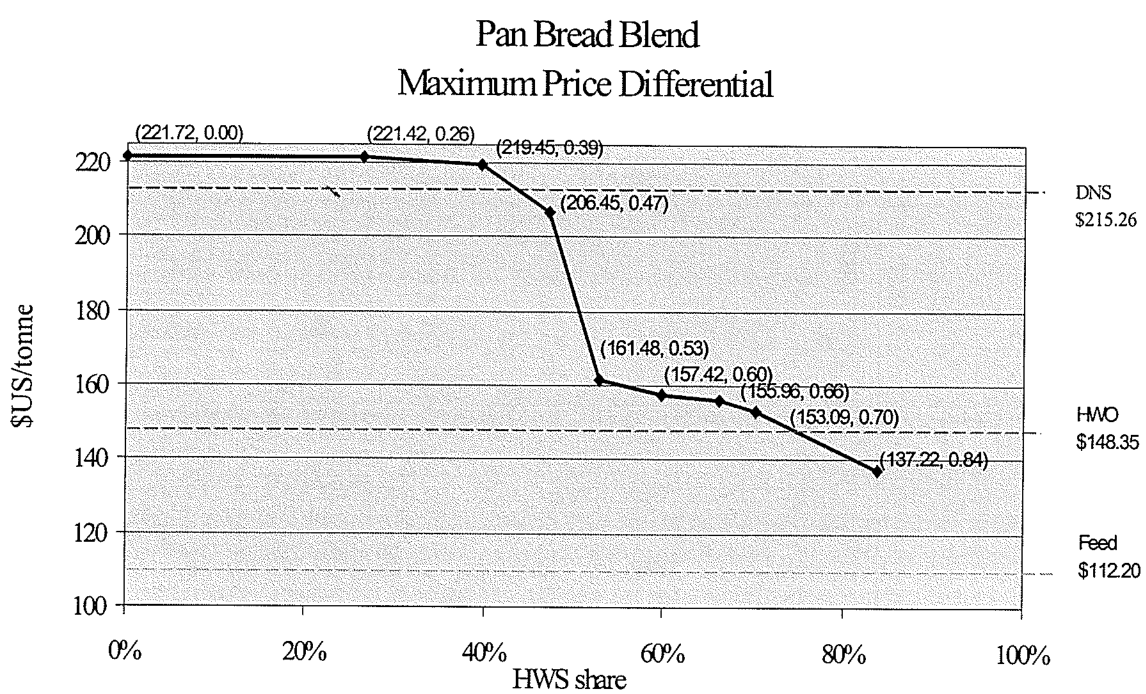
When applying a price structure that represents a period where protein premiums were at a maximum level, in other words, lower quality wheats are relatively inexpensive compared to the higher quality wheats, DNS is at a price of US$215.26/mt, and HWO is at a price of US$148.35/mt. At this price structure, with HWS excluded from the blend, HWO dominates with 38.8% of the flour blend, while 1DNS 14% composes 26.2%. 3CWRS, and lower quality HWS represent the lower quality wheats which comprise the remainder of the blend.

HWS enters the blend at a price of US$221.42/mt, a US$6.16/mt premium to the market price of high quality red wheat. At this price, HWS makes up 26.4% of the flour blend. Again, HWS substitutes entirely for DNS at this point. With further price reductions resulting in a price premium to DNS of US$4.19/mt, HWS comprises 39.4% of the pan bread blend. At price equivalency to the market price for high quality red wheat, HWS would comprise about 40% of the flour blend for pan breads.

Reducing the cost of HWS so as to be at a price discount to DNS of US$8.81/mt increases the rate of HWS acceptance to 47.1%. At this price level, a large price reduction is required to induce more HWS to enter the blend. As lower quality wheats are relatively inexpensive in this market situation, larger portions of low quality wheats are seen in the solution, substituting as much as possible for expensive high quality wheat. This demonstrates that in this market situation, if there is any chance of millers using lower quality wheat in their blends, it would be beneficial for them to do so.

Decreasing the price of HWS first allows for replacement of other high quality wheat, then allows for the substitution of lower quality wheats which had a large share due to their price advantage. In this example, DNS is first eliminated from the blend as HWS price is reduced, while standard quality wheats such as 3CRWS and HWO usage are next to be reduced as HWS price becomes less of a cost concern. Further reducing the price allows for replacement of lower quality wheats, as these wheats become less of a bargain relative to HWS, and hence substituted in favor of high quality HWS. HWS is maximized at 83.8% of the mix.

Figure 4.3



The right hand side constraints which were binding most often in this scenario were the protein content, and Farinograph stability. This indicates that the overall cost of the flour could have been reduced with more relaxed tolerances for these particular characteristics. Protein content was the chief binding characteristic, as larger shares of relatively inexpensive lower quality wheat maximized this constraint. Sensitivity analysis gives evidence of this as protein content generally has large shadow prices associated with it. Limiting characteristics of protein content, and Farinograph stability associated with lower quality wheats where seen when large portions of lower quality wheats were included in the blend. However, as HWS price was reduced and usage increased, these binding constraints became less of a factor as more high quality wheat was added to the mix.

4.1.6 Implications

This study seems to verify the intuitive notion that more low quality wheat would be used in the blend in order to achieve cost effectiveness. Some degree of high quality wheat must be maintained however, as lower quality wheat cannot fully meet the quality specifications of the pan bread flour. The derived demand curve for HWS (Figure 4.3) shows more price inelasticity below the price of DNS and is highly price responsive above the price of DNS. This suggests that since low quality wheats are priced relatively low in this scenario, HWS would require substantial reduction in price in order to compete. While at prices above that of DNS, it would be quickly substituted by other high quality wheats.

4.2 Summary

In the predominant market situation where high quality wheat garners a premium over ordinary quality wheat of about US$13.85/mt, HWS can be demonstrated to be a very competitive wheat in the domestic pan bread industry. In this scenario, the model revealed that HWS could achieve a premium of up to US$2.69/mt over that of other competing high quality wheats (e.g. DNS, 1CWRS), while maintaining 52.8% market share in the pan bread flour blend. Furthermore, at an equivalent price to other high quality wheats, HWS share could increase to about 56%, making it a considerable competitive factor in this industry.

As expected, HWS competes most closely with other high quality red wheats such as 1DNS 14% and 1CWRS 13.5%. The model shows a high degree of substitutability between HWS and other high quality wheats around the market price for high quality red wheat. As observed in Figure 4.2, the derived demand curve for HWS is very elastic around the market price for high quality wheat, hence, HWS share is increased or reduced dramatically at small discounts or premiums to other high quality wheat.

In the market situation where there is an abundance of high protein wheat on the market, the price spread between high protein and ordinary protein wheat is very narrow, therefore, high quality wheat is relatively inexpensive compared to ordinary protein wheat. In the model, a marketing year was selected where this price spread was at a level of US$4.48/mt. In this marketing environment, HWS again competes closely with other high quality wheats, however, since large amounts of high quality wheat are available at relatively inexpensive prices, a large HWS premium cannot be achieved over that of other high quality red wheats, otherwise it would be replaced. The model indicated that HWS could realize a price premium over DNS of US$0.95/mt, at which point it would make up 57.0% of the flour blend.

The other extreme market situation is where there is a shortage of high protein wheat, thereby inducing a large premium to be paid for high protein wheat. A marketing year was chosen for the model where the premium paid for high quality wheat was at a record level of US$66.91/mt. Since the price paid for high quality wheat is relatively high, the model indicates that in order to minimize costs, a larger portions of lower quality, less expensive wheats will be used in the blend, to the extent that the quality specifications can sustain their usage. The model indicated that HWS would achieve a price premium to that of high quality red wheat of US$4.19/mt, and at this price, would have 39.4% share of the flour blend. The model suggests that while some quantity of high quality wheat must be maintained in the blend, which allows for HWS to enter the blend at a premium price, combinations of other lower priced wheat do not allow for as large a share to be realized at the premium price.

Chapter 5 Results of Specialty Flour Analysis

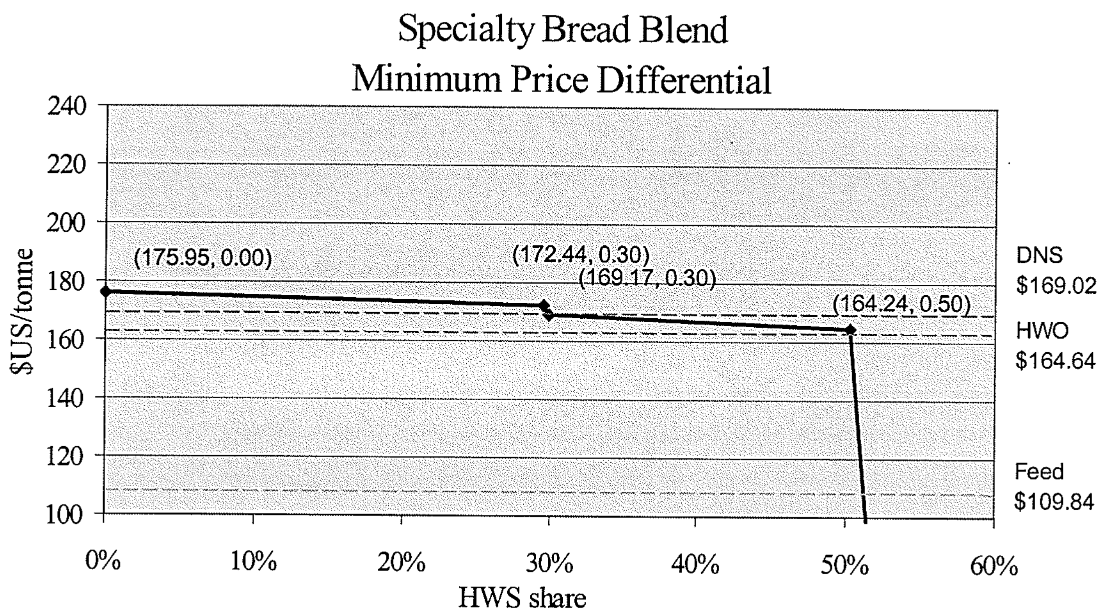
5.1 Introduction

As with the pan bread analysis, three market settings are used to evaluate the demand for HWS in specialty flours, representing the largest, smallest, and average price differential between high quality and standard quality wheats. The range of prices applied to each type of wheat represents the competitive setting that HWS would have encountered between 1980 and 1998, and represents the likely range of market prices HWS would encounter in the future. Hence, the pricing and utilization of HWS depends closely upon the relative prices of alternative wheats in each market setting.

5.1.1 Minimum Price Spread between Low and High Quality Wheats

In the market scenario where high protein wheat is in abundance, and protein premiums are relatively low, the relative annual prices of DNS and HWO are US$169.02/mt, and US$164.64/mt respectively. The resulting spread is only $US 4.38/mt. High protein wheat dominates the specialty flour blend, with DNS at a 79.4% share, and the remainder supplied by low quality wheat (3CWRS). In this situation, HWS first enters the blend at a price of US$172.44/mt. At this price it composes 30% of the flour blend and is at a premium of US$3.42/mt to DNS. HWS substitutes directly with DNS at this price. HWS usage is increased to 50.2% of the blend with further price reductions, but is at a discount to DNS of US$4.78/mt. To reach this point, HWS substitutes for the lower quality wheat (3CWRS) that existed in the blend. Further reduction in the price of HWS does not increase its share in the blend, due to a large percentage of sound, high quality wheat being required in order to ensure a satisfactory level of protein, and acceptable levels of enzymatic activity are maintained in the flour.

Figure 5.1



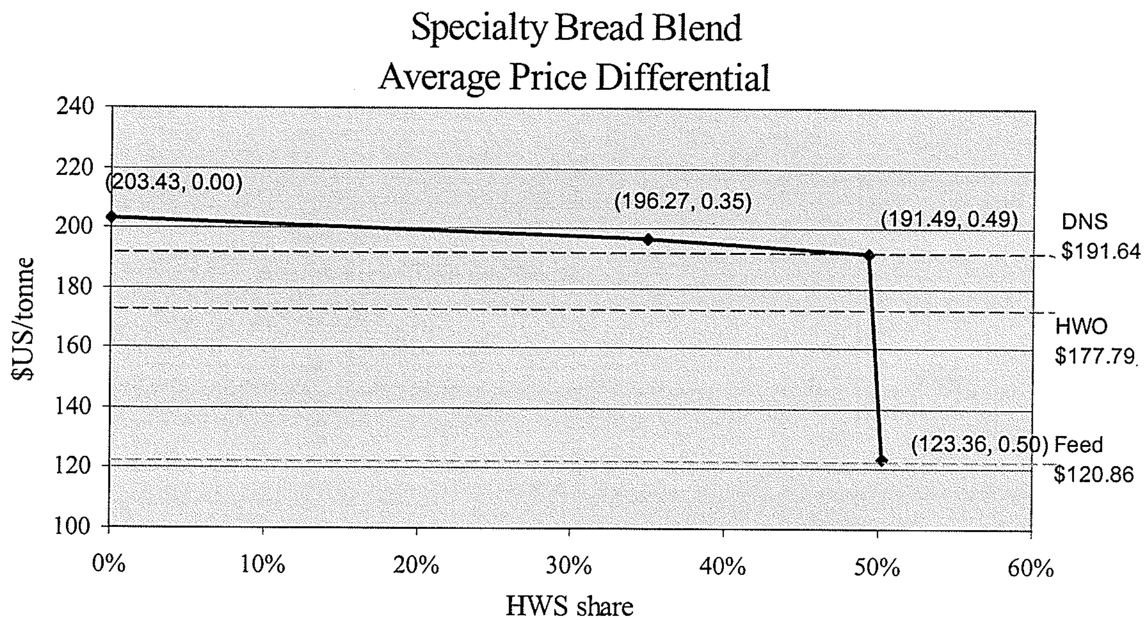
Protein and liquefaction number (LN) were the constraints which contributed most to determining the optimal blend of wheats. Specialty flour has an inherent need for high quality wheats, as the end products of this type of flour require wheat with high protein, stability, gluten strength, and kernel soundness. These demanding requirements tend to exclude wheats of lower quality from entering into the blend.

It can be noted from the results of the simulations that the shadow prices for LN become increasingly large as more HWS is added to the blend. Hard white wheat, being a high quality/high protein wheat is suitable to enter the blend for this type of flour but at a rate that is limited by its contribution to the LN level. White wheat, with a tendency for high LN level, will have a maximized usage (given appropriate pricing) at the point where the flour has reached the desired level of LN. Given that improved sprouting resistance is being bred into new lines of HRS, this factor becomes overstated in this model and in reality will be less of a concern.

5.1.2 Average Price Spread between Low and High Quality Wheats

In the scenario representing the average protein premium prevails, DNS is priced at US$191.64/mt, and HWO is priced at US$177.79/mt, resulting in a protein premium of US$13.85/mt. High quality reg wheat (DNS) dominates in this situation with 84.8% of the blend. HWS enters the blend at a price of US$196.27/mt. At this price HWS is at a premium to DNS of US$4.63/mt and has a 34.9% share of the flour blend. Hard white wheat shows a high degree of substitutability with high quality red wheats as it substitutes directly for DNS at this point. Reducing the price of HWS by US$4.78/mt (a $0.15/mt discount to DNS) increases its share of the blend to 49.3%. Further reductions in HWS price do not significantly increase its usage in the blend, due to constraining characteristics. At price equivalency to high quality red wheat, HWS would maintain near a 50.0% share of the flour blend.

Figure 5.2

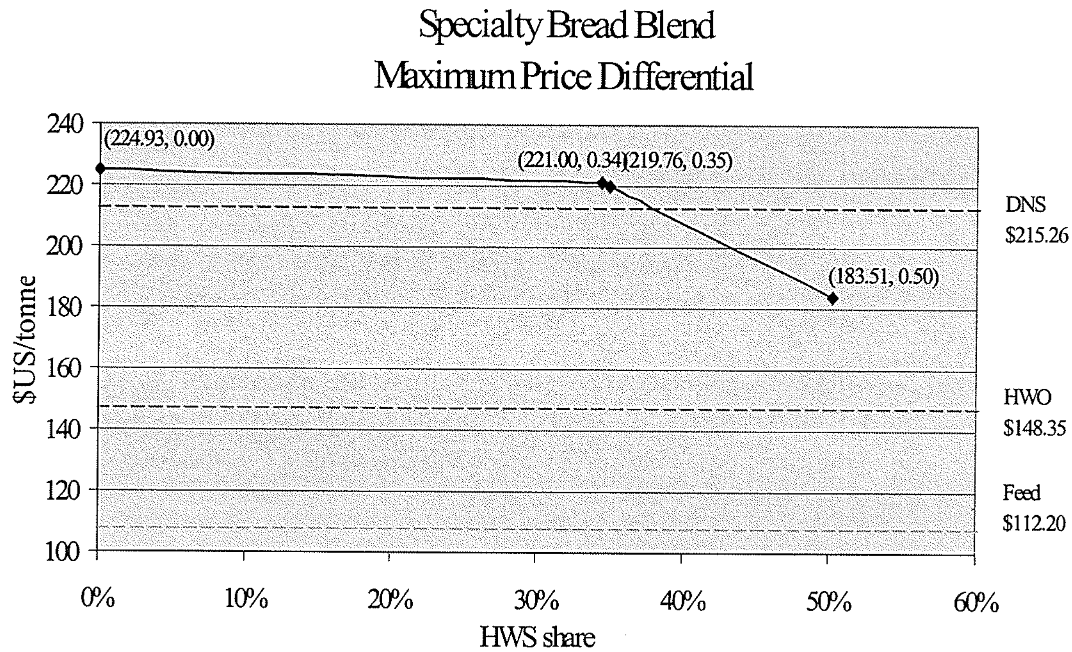


The constraints that were binding in this situation were protein content and LN. Naturally, with the higher protein requirement of this flour, protein level was a constraining factor throughout each simulation, thus not allowing for inexpensive lower quality wheats to enter the solution. As HWS entered the solution, LN became another binding value. The shadow price for LN becomes larger as the price of HWS is reduced and more HWS enters the blend, indicating that the final cost of the flour could have been lowered given the opportunity for more relaxed specifications on kernel soundness, allowing more HWS to enter the solution. Again, high quality standards for kernel soundness in this flour type translates into a mitigating factor for white wheat acceptance, due to its tendency of more sprout damage. Again, given that advancements in sprouting resistance can be achieved during the development of HWS, LN would not be a significant limitation, allowing HWS to increase its share of the blend.

5.1.3 Maximum Price Spread between Low and High Quality Wheats

For specialty flour products, the dominant wheat used to satisfy quality specifications is high protein hard wheat. Before high quality HWS is allowed to enter the solution, the optimal blend for this flour type contains 84.1% DNS, while the remainder is made up of less expensive lower quality HWS. When applying the market scenario where the protein premium for high quality wheat is at its highest level, DNS is at a price of US$215.26/mt, while HWO is at a price of US$148.35/mt, for a price spread of US$66.91/mt. When adjusting the price of HWS, it first enters the solution at a price of US$220.99/mt. At US$220.99/mt, HWS is at a premium to high quality wheat of US$5.73/mt and has a 34.4% share of the specialty flour blend. HWS share of the flour blend was nearly in direct substitution for DNS, which decreases to 50.1% share. At price equivalency to high quality red wheat, HWS would make up about 34% of the flour blend for specialty flours. Further price reductions to US$183.51/mt increases HWS contribution to the flour blend to its maximized level of 50.2%. At this price however, HWS is at a discount to high quality red wheat of US$31.75/mt. At this point, lower quality HWS is substituted out as the higher quality wheat becomes relatively less expensive.

Figure 5.3



The demanding specifications for this flour type becomes a large factor in determining the optimal blend, and precludes the significant usage of anything but the highest quality wheats in the blend. Protein content and LN are the chief limiting characteristics which determine the optimal blend for this flour product. Protein content has a high shadow price of around $40/mt throughout the simulations. This means that the cost of the flour could be reduced by about $40/mt given a relaxation of the protein specifications by one unit, allowing more lower priced wheats to enter the blend. This is not possible however since the strict protein requirements demand a large share of high quality wheat in the blend.

5.2 Summary

As the quality specifications for specialty flour are very demanding, millers will exhibit relatively inflexible demand for high quality wheat for the purpose of blending different wheats. These quality demands may prohibit the large-scale usage of wheats that may have one or several low quality characteristics. This is evident in the model which suggests that high quality wheat such as 1DNS 14%or 1CWRS 13.5% would be the favored wheat to mill for specialty flour. Given the appropriate price, HWS may enter the blend, substituting for 1DNS or 1CWRS up to a rate that tends to be limited by its level of enzymatic activity. As sprouting damage tends to be characteristic of white wheat, this may result in being a limiting factor for HWS acceptance in specialty flours. However, under average crop and market conditions, the model suggests that HWS could enter the blend for specialty flours at a rate of 49.3% at the market price for high quality wheats, or a rate of 34.9% and have a modest premium over the market value for high quality wheat of US$4.63/mtonne.

Chapter 6 Results of Japanese Noodle Analysis

6.1 Introduction

With low protein content requirement of Japanese-style noodle flour (9.0-10.5%), as well as low gluten strength needs, high quality HWS is not well suited to be milled to this product. Flours with low protein and gluten strength result in a soft, chewy product preferred by consumers. A lower quality hard white wheat may be more suited for this type of flour than the high protein hard white spring wheat analyzed in this study. As demonstrated in the model, only a small percentage of HWS is included in the blend of Japanese noodle flour in any given market condition.

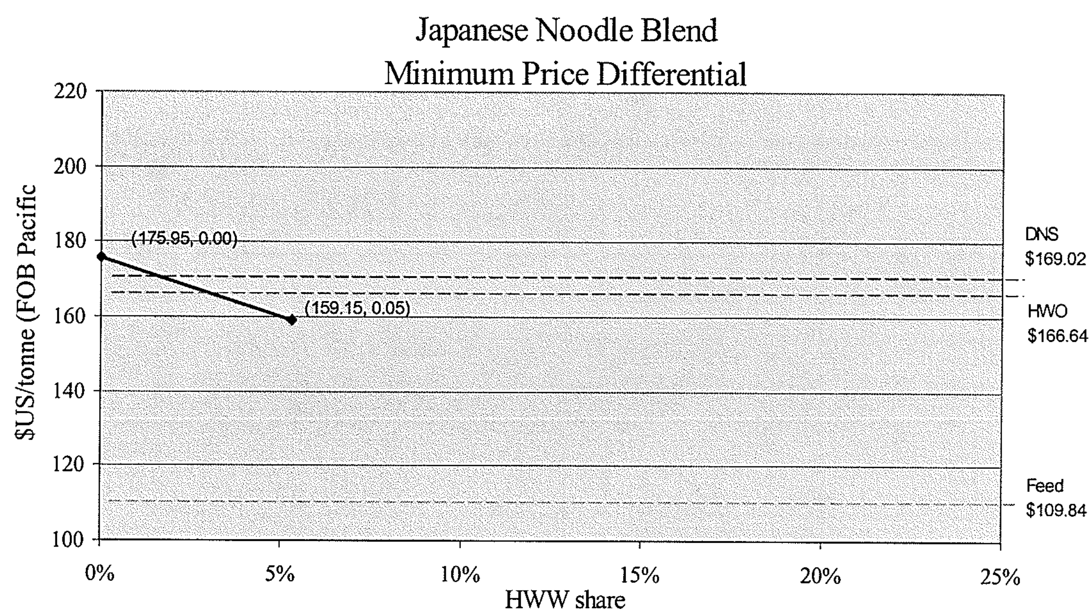
As in the domestic flour analysis, three market settings are employed to determine the pricing and usage of HWS. The market situation represents that of low, average, and high price differentials between high and lower quality wheat.

6.1.1 Minimum Price Spread between Low and High Quality

No amount of HWS enters the Japanese-style noodle flour blend at prices equivalent to those of high quality red wheat (DNS). The blend is dominated by wheats of Australian origin, with ASW at 57.1% and APH at 38.2% of the blend, respectively. HWS enters the blend at a price of US$159.15/mt (FOB Pacific), which represents a US$9.87/mt discount to DNS. HWS usage is also maximized at this price. No further price decrease would allow for more HWS in this flour. High protein content and strong Farinograph stability levels found in HWS represent barriers for increased usage in the Japanese-style noodle flour. This is evident in the analysis of binding characteristics in the flour.

Protein content and Farinograph stability were the quality characteristics which determined the optimal composition of wheats in the blend. The lower protein and stability levels of ASW appear to be most suited for the end product; therefore its usage is not displaced by reducing the price of HWS.

Figure 6.1

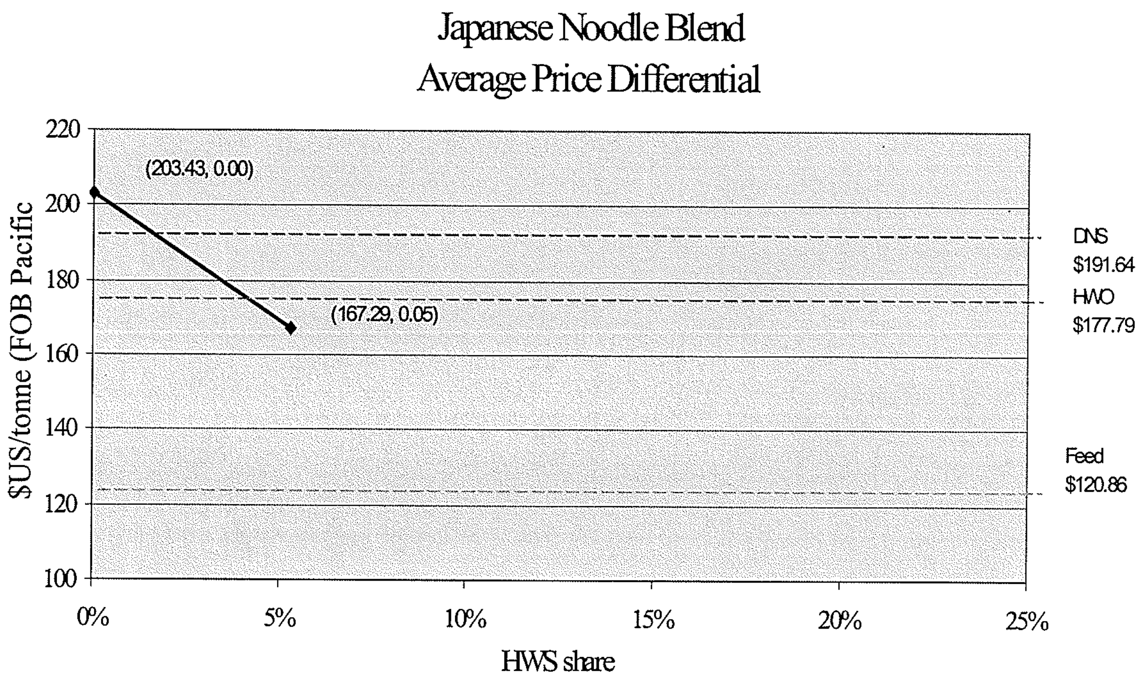


6.1.2 Average Price Spread between Low and High Quality Wheats

In the typical market situation, where an average price spread exists between high quality and low quality wheat (US$13.85/mt), HWS does not figure into the blend for Japanese style noodles when priced equivalent to 1CWRS 13.5%. In this market setting, the model indicates that the end product could be composed at the least cost, by a mixture of standard quality white wheat (ASW 45.5%), high quality white wheat (APH 32.4%), with the remainder made up of lower quality wheat (Trigo Pan 22.2%).

HWS is able to enter the solution when its price is reduced to US$167.29/mt. At this price, HWS comprises 5.3% share of the flour, and is at a price discount of US$24.36/mt to high quality red wheat. When the price is dropped to US$167.29, it is maximized as an ingredient in Japanese Noodle flour.

Figure 6.2



Again, protein and Farinograph stability are the flour quality characteristics that determine the final composition. The shadow prices associated with these binding characteristics are much larger than in the market situation involving the minimum protein premium. This suggests that as the price spread between high and low protein wheat widens, the cost pressure on the flour specifications becomes greater. Again, the principal wheat used in this blend is ASW, which seems to possess the fundamental quality characteristics required to produce the end product. High protein hard spring wheat does not seem to adequately meet the flour specifications to achieve more than a modest share of the flour blend. This is consistent with findings from other studies:

> "Therefore, ASW wheat is the principal; raw material for milling Japanese noodle flour, but some soft wheats such as Japanese wheat and/or U.S. western white wheat are often blended with it. Hard wheat flour, even at low protein content, is not suitable for Japanese noodles. For the manufacture of noodles with a little firmer texture, however, a small amount of hard wheat flour may be blended with soft wheat flour."[46]

6.1.3 Maximum Price Spread between Low and High Quality Wheats

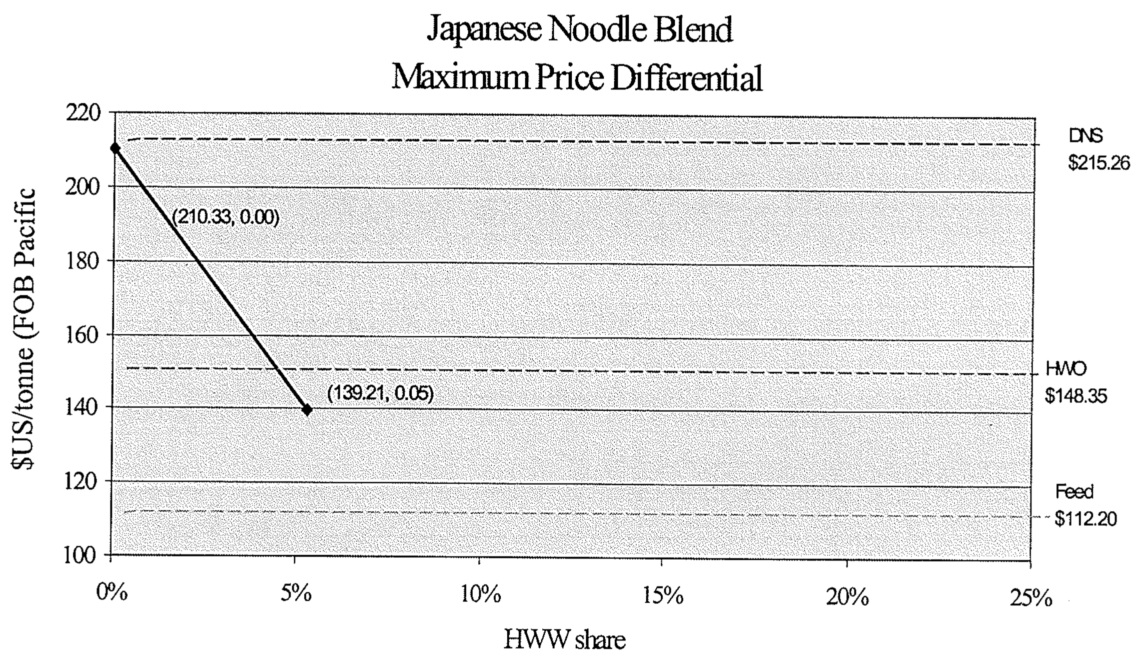
When the market scenario of historical maximum price spreads between high and low quality wheat exists, similar results are found as observed in the previous market situations. The preferred wheats are ASW (45.45%) and APH (32.4%), with the remainder supplied by a lower quality wheat in Trigo Pan (22.2%).

HWS gains entry to the blend at a price of US$139.21/mt, where its usage is maximized at 5.3%. At this price, HWS is at a large price discount to the market price of high quality wheat of US$76.051/mt. Clearly, high quality wheat must compete more directly against lower quality and lower priced wheats for acceptance in this blend, as combinations of those low priced wheats are adequate to produce a suitable flour. Therefore, large price discounts are required before HWS can gain any inclusion into the flour. It would appear that as the North American market for high protein pan breads drives the price for the high quality wheat, this in turn requires that high quality HWS take a significant price discount in order to compete in the Japanese noodle market

46 James E. Kruger, Robert B. Matsuo and Joel W. Dick, *Pasta and Noodle Technology.* (St. Paul: American Association of Cereal Chemists, Inc., 1996) 186.

against standard quality wheats. It would reasonable to conclude that ASW is the wheat which represents the standard wheat which other wheats need to compete against in this market.

Figure 6.3



6.2 Summary

As discussed, the model suggests that high quality HWS would not be suitable to secure a large share of Japanese-style noodle flour. Combinations of other lower quality wheat appear to be more suited to producing this product. However, HWS may be blended in as a supplemental wheat at price levels below that of high quality wheat. Clearly, the model indicates that standard quality wheats are more suited to the product; therefore HWS would have to compete against the prices of these wheats for usage in the flour blends.

A limitation of this model is that a highly important measure of quality for Japanese-style noodles is the starch swelling capabilities of the wheat. The model does not account for this characteristic, as there is no measure to effectively capture this effect across all types of wheat used in the LP.

Chapter 7 Results of Chinese Noodle Analysis

7.1 Introduction

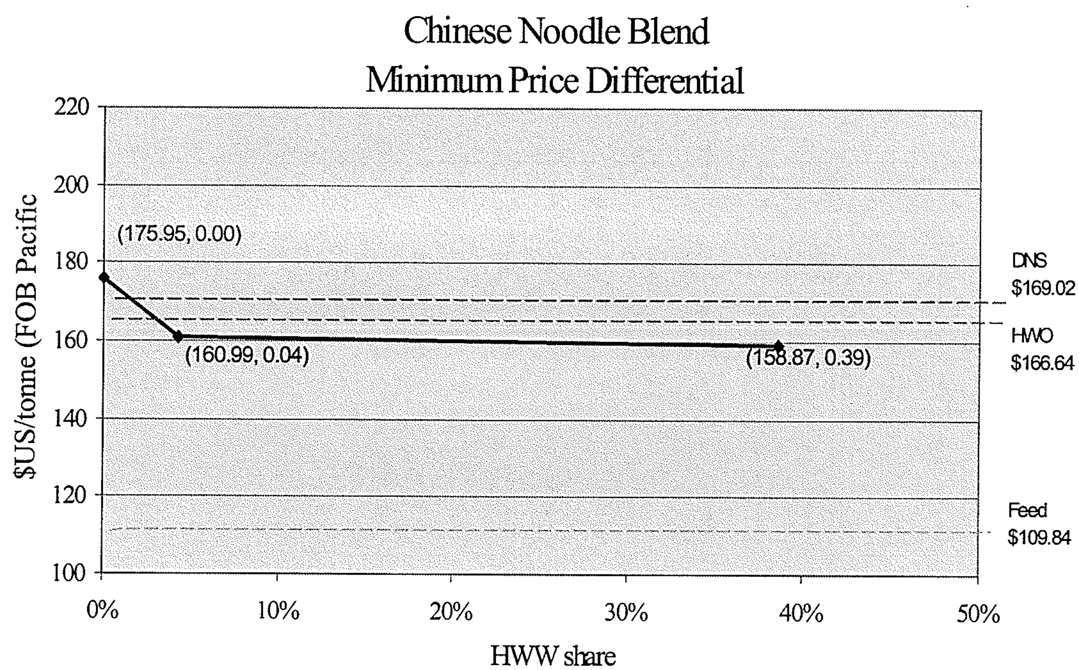
In terms of Asian noodle production, HWS would likely be relatively better suited to the Chinese-style noodle flour than Japanese-style noodle flour. Protein content tends to be much higher for this type of noodle (10.5%-12.0%), allowing for a more firmly textured product. Hard wheats are used commonly in Chinese noodle production, often the same flour blended for Chinese-style noodles can be used in pan bread production.

Again, the three market settings representing situations of low, average, and high price differentials between high quality and lower quality wheat were used in the simulation to represent the range of possible market conditions HWS would encounter. Hard white wheat pricing and usage is then analyzed under each market setting.

7.1.1 Minimum Price Spread between Low and High Quality Wheats

When there is a minimal price differential between lower and higher quality wheats, and HWS is priced equivalent to 1CWRS 13.5% (US$175.95/mt), no amount of HWS enters the flour blend. In this market setting, the wheats selected by the model to produce a suitable Chinese noodle flour are APH (68.0%) and EU soft wheat (32.0%). As indicated by the model, Chinese noodle flour can be made employing a large share of high quality hard white wheat in the blend. At price equivalency to the domestic North American price of high quality wheat (US$169.02/mt), HWS does not enter the solution. A price of $US160.99/mt for HWS allows for HWS to enter to the blend at a share of 4.3%, substituting for portions of both APH and EU wheat. When the price of HWS is dropped to US$158.87/mt it enters the flour blend at 38.5% of the wheat milled. At this price, HWS is at a discount to the market price of high quality wheat of US$10.15/mt. HWS usage is maximized at this level. As HWS entered the solution, the level of APH is decreased by way of substitution. The final result is a blend consisting of APH (36.0%), ASW (25.4%), and HWS (38.5%).

Figure 7.1



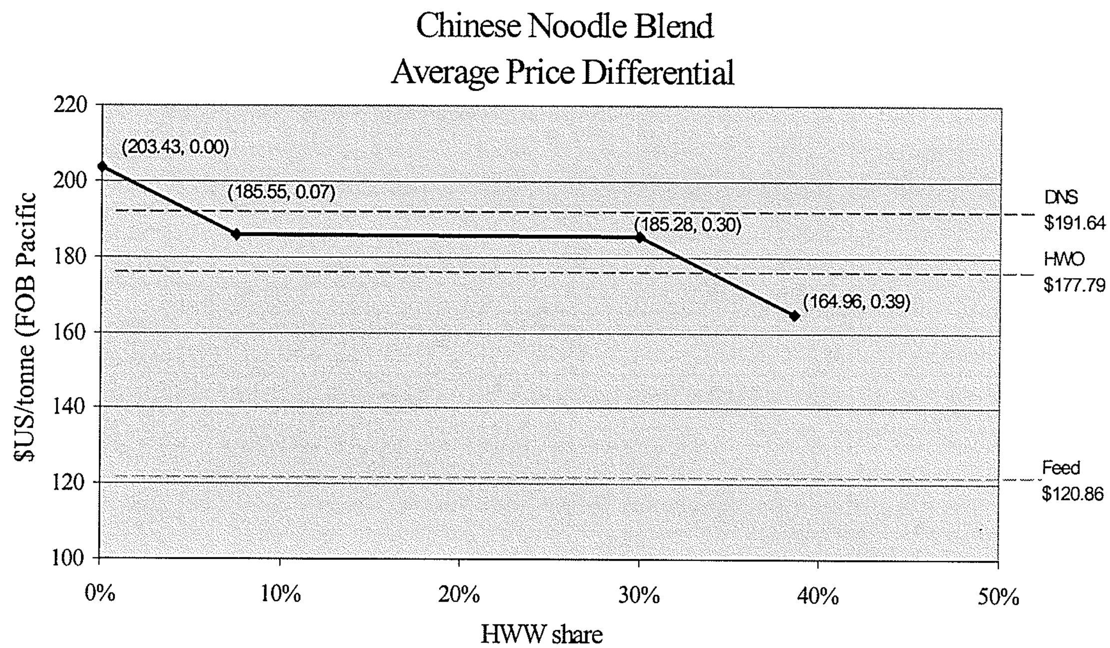
Farinograph stability level in the flour was the main characteristic which determined the optimal blend of wheat flours, while protein content also became a factor as HWS entered the flour blend. Farinograph stability level has a small shadow price in the simulations because a lower cost flour blend could be achieved given more relaxed stability specifications, allowing more low priced, low quality wheat to enter the blend. However, Chinese noodles require a somewhat firmer end product, which requires a flour which does not quickly break down. As more HWS enters the blend, the protein limit is maximized and becomes binding.

7.1.2 Average Price Spread between Low and High Quality Wheats

In the typical market situation represented by the average price differential between low and high quality wheats, the least-cost model suggests that the flour could be made by a blend of: 1DNS (44.4%), APH (18.8%), Trigo Pan (31.9%), and CPSW (4.9%). When HWS is priced equivalent to 1CWRS 13.5% (US$203.43/mt), it does not enter the blend.

When parametrically reducing the price of HWS to US$185.55/mt, a discount to DNS of US$6.09/mt, HWS would enter the blend at a rate of 7.4%, resulting in reduction in usage of DNS, APH, and CPSW in the blend. A further small reduction in price to US$185.29/mt ($6.35/mt discount to DNS), would allow for an increase in HWS usage to 29.9%. At this price, HWS substitutes for DNS in the flour. The model suggests that demand for HWS would be very elastic at prices just below the market price for high quality wheat. Further price reductions in HWS would allow for increased usage, however, to a lesser extent. At a point where HWS comprises 29.9% of the flour mix, larger decreases in price result in lesser increases in usage, as HWS must be priced low enough to substitute for other low priced, inferior quality wheats. HWS usage is maximized at 38.5% at a price of US$164.96/mt. At this point HWS would be at a US$26.68 /mt discount to DNS and a US$12.83/mt discount to HWO.

Figure 7.2



As previously discussed, protein content and Farinograph stability levels are the key flour quality characteristics responsible for determining the blend of wheats to be used. Flour color is also a characteristic which influences the final blend when larger amounts of hard red wheat is present. However, as HWS price is reduced, and larger portions of HWS replace the red wheats in the blend, flour color becomes less of a factor.

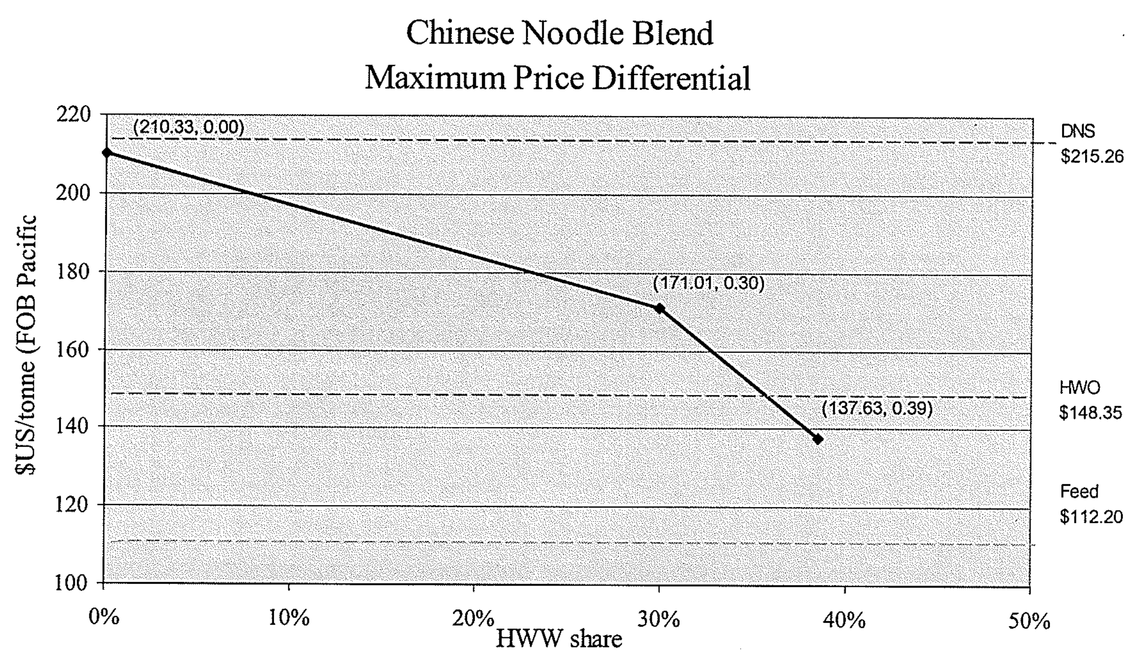
7.1.3 Maximum Price Spread between Low and High Quality Wheats

The model was applied to the circumstance where wheat prices represent the historical maximum price spread between high and low quality wheat. In this situation, a suitable flour could be achieved by a blend of high quality white wheat (APH 41.7%) blended with lower quality wheat (58.3%). When HWS price was set equal to 1CWRS 13.5%

(US$210.33/mt), HWS would not be included in the blend of wheats used to produce flour for Chinese-style noodles.

Hard white wheat becomes part of the blend at a price of US$171.01/mt, or a US$44.25/mt discount to the price of high quality wheat (DNS). At this price, HWS composes 29.9% of the flour blend and substituted for portions of both the high quality APH and the lower quality Trigo Pan. As HWS price is further reduced to US$137.63/mt, HWS composes 38.5% of the blend, while Trigo Pan is eliminated from the blend and some ASW is able to enter the blend. At this price, HWS usage is maximized, and is at a discount to DNS of US$77.63/mt and to HWO of US$10.72/mt.

Figure 7.3



Again, Farinograph stability level of the flour was the main binding characteristic observed, with protein content also becoming binding as HWS levels increased, and the tolerance for high protein wheat was reached.

7.2 Summary

HWS could comprise a significant share of the flour blend for Chinese noodle flour. However, it would likely do so at a price below that of the domestic North American price for high quality red wheat. The model suggests that it would be difficult to have HWS contribute to making a suitable noodle flour at a premium price, given the other possible combinations of wheats, which would mitigate against it. In particular, Australian wheats ASW and APH appear to have desirable noodle qualities and may also benefit from a freight advantage due to its proximity to the market. The flour quality specifications of Chinese noodle flour are such that, while significant amounts of high quality wheat can be applied in the blend, they must compete with combinations of lower quality wheats that allow millers to be price discriminatory. Hard white wheat of Canadian origin would likely have to be discounted from the domestic market price of high quality red wheat in order to enter the export market for Chinese noodle flour.

Chapter 8 Results of Flat Bread Analysis

8.1 Introduction

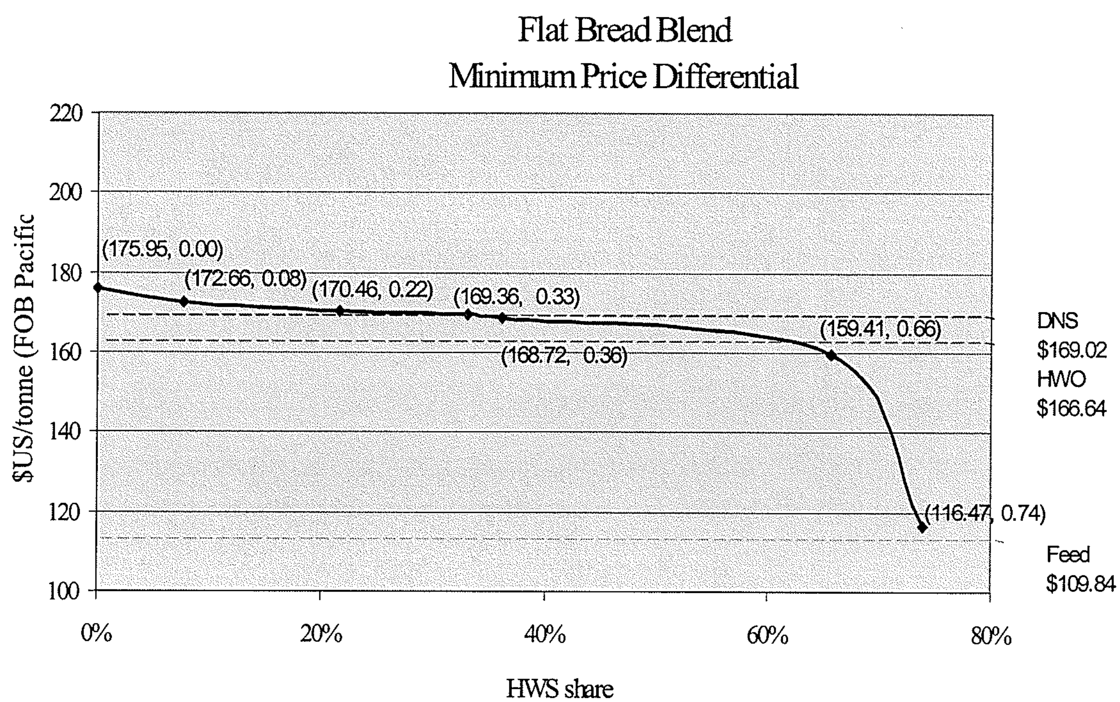
Flat breads are typically produced from flour that has undergone a high degree of extraction, which concurrently results in a very high ash content. Coloration is also a very important factor in production of flat breads, and red wheat is typically not used as base for this flour due to its tendency for the darker color to dominate following the higher extraction rates. The derived protein content for flat bread flours tends to be in the midrange (10.5%-12.0%). For these reasons, hard white wheat would appear to have more desirable characteristics in flat bread production than hard red wheat.

To assess the pricing and usage of HWS, three market settings were used in the simulations. Market settings of low, average and high price differentials between high and low quality wheat were used to represent the market conditions HWS would encounter.

8.1.1 Minimum Price Spread between Low and High Quality Wheats

When the market condition of historically low protein premiums is applied to the model and high quality HWS is priced equal to 1CWRS 13.5%, it does not enter the flour blend. In this market setting, a suitable flat bread could be made by a blend of WW (41.0%), 3CWRS (30.4%), EU soft wheat (13.6%), and low quality HWS (15.0%). At the price of US$172.66/mt, HWS becomes part of the mix at 7.7% and at this price, it is at a modest price premium of US$3.64/mt to the domestic North American price of high quality wheat (DNS). As HWS price is further reduced, HWS substitutes first for other spring wheats (3CRWS), then lower priced wheats (WW and EU soft wheat). According to the derived demand simulated by the model, when priced equivalent to DNS, HWS would make up about 22.0% of the flat bread flour grist. Substitution is very elastic with small decreases in HWS price until HWS constitutes 65.7% of the blend and is priced at US$159.41/mt. After this point, the demand becomes rather inelastic with further decreases in HWS price. At US$159.41/mt, HWS would be at a price discount to DNS of US$9.61/mt. HWS content in flat bread flour is maximized at US$116.47/mt, composing 74.0% of all wheats being milled.

Figure 8.1

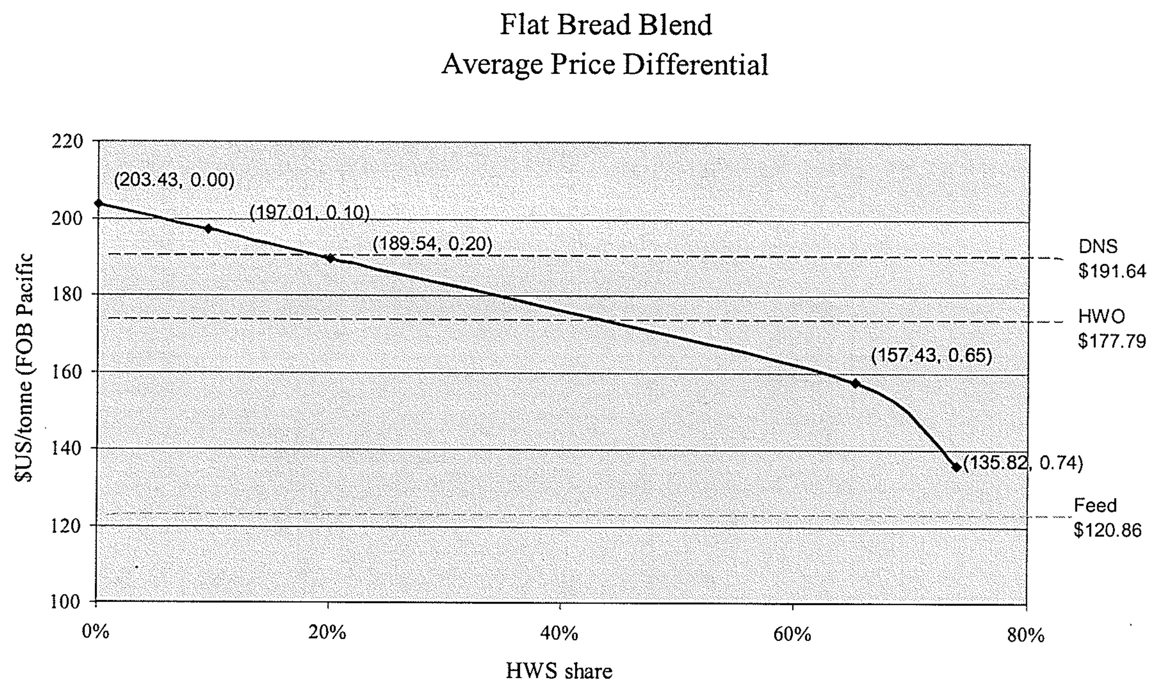


Protein content and extraction rates were the main characteristics that determine the optimal blend of wheats for flat bread flour. Extraction rates demand for flat breads, as expected, require wheats with high extraction capabilities and white color. As the HWS share increased in the flour, extraction rates of the flour becomes less of a concern, however, protein content of the high quality HWS becomes a maximized constraint. Farinograph absorption also became a limiting factor in the blend when larger amount of low quality wheat was included. Again, as HRS usage was increased in the blend, this constraint becomes slack.

8.1.2 Average Price Spread between Low and High Quality Wheats

Applying the average market situation to the model showed that flat bread flour would best be made of a blend of CPSW (75.5%), DNS (9.5%) and low quality HWS (15.0%), while no amount of high quality HWS is included in the blend at a price equivalent to that of 1CRWS 13.5%. High quality HWS becomes part of the blend at a price of US$197.01/mt, which represents a US$5.37/mt premium to the market price of high quality red wheat (DNS). At this price, HWS constitutes a 9.5% share of the blend. As the HWS price is reduced, it first substitutes entirely for DNS, then for lower quality HWS, and CPSW respectively. HWS usage is less price responsive than in the market situation where protein premiums are smaller. At price equivalency to DNS, HWS would make up about 15.0% of the flour blend. At prices below DNS and HWO however, would allow for a larger portion of HWS to enter the flour blend. HWS usage is maximized at 74.0% of all wheats milled, at a price of US$135.82/mt. This represents a discount of US$55.82/mt to the market price for high quality wheat.

Figure 8.2

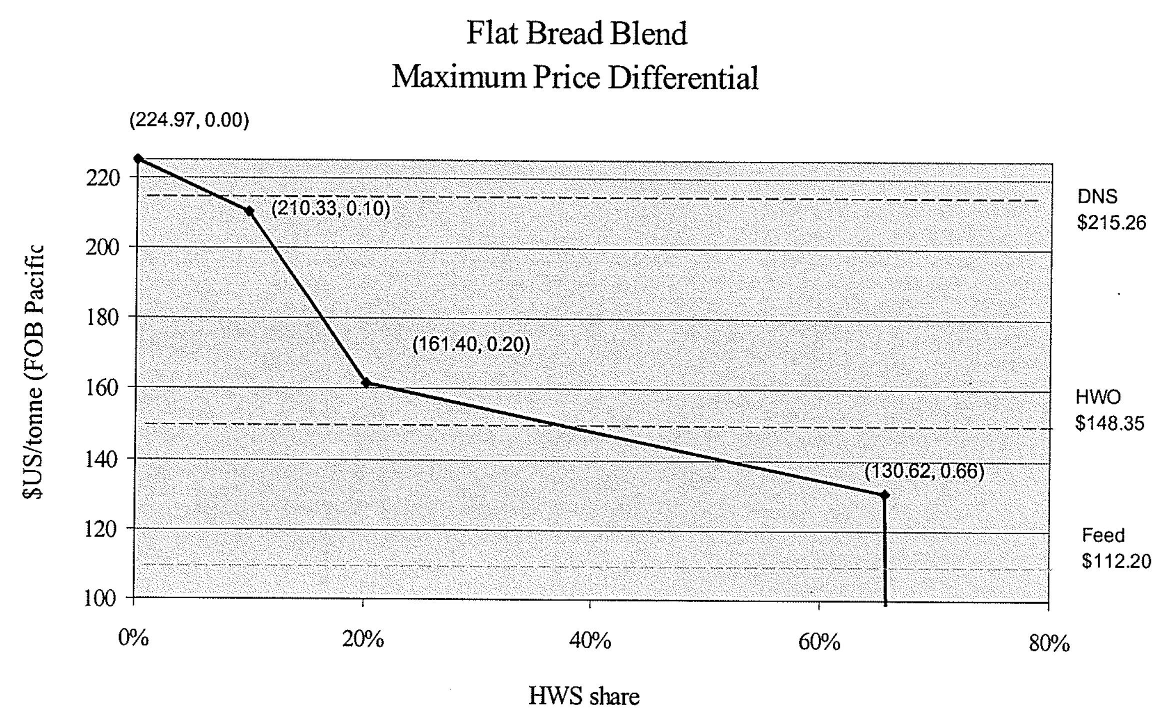


Protein content is the only flour characteristic that becomes binding in this market situation. At prices where HWS is priced in line with other high quality wheats, the blend favors lower quality and lower priced wheats, resulting in the protein content of the flour to be limiting on the low end of the range. As HWS price is reduced and more HWS included in the blend, protein content becomes limiting on the high end of the acceptable range for this flour.

8.1.3 Maximum Price Spread between Low and High Quality Wheats

When examining the market scenario of the largest protein premiums, a larger percentage of low quality wheats are able to make up the blend due to very low prices compared to high quality wheat. With HWS priced equal to 1CRWS 13.5%, it composes 9.7% of the blend for flat bread flour. The rest of the blend in composed of CPSW (56.6%), EU soft wheat (18.7%), and low quality HWS (15.0%). The model shows that HWS could maintain a 9.7% share up to a price of US$224.97/mt. This represents a US$9.71/mt premium to that of DNS. Above this price, HWS would be substituted by high quality hard red wheat, 1CWRS 13.5% in this case. When priced equivalent to DNS, the market price indicator for high quality red wheat, HWS would comprise about 8.0% of the flat bread flour blend. HWS would be maximized in the blend at a price of US$130.62./mt, at which point it would make up 65.7% of the flour blend for flat bread. This represents a discount to high quality wheats of US$84.64/mt.

Figure 8.3



Compared to the other market scenarios analyzed, this market would require larger decreases in the price of HWS to increase its share of the flour blend. Lower priced low quality wheats prove to be difficult to displace in this flour without large discounts in the price of HWS. As the price premium for high quality wheat increases, less high quality is included in the blend, as flat bread flour appears to have higher tolerances for lower quality wheat, and therefore millers would maximize the usage of these lower priced wheats for their blends.

8.2 Summary

The model shows that HWS could enter the flour blend for flat breads as it exhibits many of the characteristics needed for flat bread flour. HWS may only comprise a limited share of flat bread flours at a premium price, as combinations of other low priced wheats would reduce its cost effectiveness to enter the blend as more than just a supplemental wheat. Priced equivalent to that of DNS, the measuring stick for high quality wheat, HWS may comprise about 15.0% of the flour blend. The model demonstrates that HWS acceptance in the flour blend would be made more difficult in scenarios of larger price spreads between high and low quality wheat. With larger price spreads, lower protein and lower prices wheats tend to render HWS too expensive given other options to purchase wheat. Similarly, with narrow price spreads between low and high quality wheat, HWS would be relatively less expensive to purchase, and therefore find higher acceptance rates at prices around that of high quality wheat.

Chapter 9 Conclusions and Implications

9.1 Conclusions and Implications

Chapter 9 offers a review of results found in the study, as well as implications for what the results suggest.

Wheat production in Canada and the U.S.A. has traditionally been made up of hard red varieties. Red wheats developed into the leading North American wheat type due to agronomic advantages over white wheats, mainly attributed to better sprouting resistance relative to white wheats. While red wheats have developed a dominant position in the domestic milling industry, it has been hypothesized that a suitable hard white wheat would have an economic advantage over red wheats. In addition, it has been suggested that HWS would be able to penetrate key export markets not adequately accessed by red wheat exports. Many large export markets such as Asian noodle markets and Middle East and Indian Subcontinent flat bread markets prefer white wheat for manufacturing their end products. These importers mainly acquire hard white wheats originating from Australia, which produces hard white wheat exclusively, and holds a large market share of the white wheat trade. White wheats currently grown in Canada are of intermediate hardness and protein level, and have shown only marginal successes in domestic and export markets. However, wheat breeding programs in Canada and the United States are making advances in developing a true hard white wheat which would be suitable to both the domestic market, as well as export markets.

As HWS approximates high quality hard red wheats in terms of quality characteristics, it would appear to be well suited to meet the requirements of domestic pan bred flours. Currently, high quality red wheats are the dominant type of wheat used in the manufacture of pan breads in North America. Hard white wheat appears to be particularly suited to usage in whole-wheat pan breads as a whiter product could be achieved relative to red wheats. Everything being equal with hard red wheat, with the exception of seed coat color, HWS usage in the domestic milling industry would expect to meet or exceed that of hard red wheat due to the extraction advantage enjoyed by HWS over red wheats. Domestic millers could theoretically increase profits relative to using red wheats due to the inherent extraction advantage of HWS. As a result, HWS could expect to achieve a significant share of pan bread flour blends, as well as receive a price premium over other high quality red wheats.

Linear programming was the method applied to simulate a wheat milling and flour blending situation which would allow for an indication of the level of usage of HWS and the relative price of HWS based on its inherent characteristics when applied to various end products. Flour quality characteristics were compiled for various wheats of Canadian, American, Australian, European, and Argentine origin for use in the model. Flour quality data averages were used to represent the quality properties for each wheat.

Three market settings were used to represent the range of market conditions HWS would expect to encounter upon entry to the market. Market conditions of high, average, and low price differentials between high quality and low quality wheat were used. These market settings would be representative of situations of low, average, and large supplies of high quality wheat availability. Historic prices (as per ICG publications) associated with each market setting were applied to each wheat. High quality HRS was priced equivalent to 1CWRS 13.5% to begin each simulation. The price of HWS was then parametrically adjusted revealing both the price level required to alter the final HWS share of the flour blend, and the level of usage at each price.

A least-cost LP blend problem allows for simulation of the rate of acceptance of HWS into various flour blends. Flour blends suitable to produce large volume pan breads, and specialty products, such as buns and rolls, were applied as representative of the domestic market. Flour blends suitable for making Japanese-style noodles, Chinese-style noodle, and flat breads were used to represent potential export markets. Flour quality parameters suitable for achieving the desired end products were determined through various technological studies as well as expert opinion.

9.2 Domestic Markets

Analysis of the linear program simulations of wheat blends suitable to produce flour used in high volume loaf breads showed that high quality hard wheat dominates the wheats used for pan bread flour. This is demonstrated in all three market situations analyzed, where high quality wheat such as DNS dominates the blend, while standard quality wheat such as HWO constitutes a minor portion. Of interest, high quality CWRS wheats do not enter the blend. This result is likely due to the fact that the prices used for CWRS wheat are CWB asking prices rather than actual sales prices, and therefore are likely overstated.

The price of DNS is a better indicator of the market price for high quality wheat. As prices for U.S. originated wheat more accurately reflect transaction prices, it would be reasonable to assume that DNS is the representative domestic price for high quality wheats. Given that high quality 1CWRS 13.5% wheat competes most closely with DNS, one could also assume that CWRS price more closely approximates that of DNS. Some lower quality wheat is also included in the blend. For example, 3CWRS is maximized at 20% of the blend. This suggests that lower quality hard wheats may have sufficient quality properties to produce high volume loaf breads, but its usage is limited due to lack of consistency of the wheat.

When priced equivalent to 1CWRS 13.5%, HWS does not enter the pan bread blend. Again, this is likely attributed to inflated CWB asking prices. On average, at the market price for high quality red wheat, HWS would realize a 56% share of the flour blend for pan breads. A greater amount of HWS can be used when the price differential between high and low quality wheat is small; the model indicated a level of 57% in this market situation. Conversely, when the differential is large, HWS share of the flour blend reduces to 40%. This demonstrates how for the domestic pan bread industry, more low priced lower quality wheat can be used in the blend when larger premiums are required to acquire high quality wheat, in order to minimize costs.

Protein content is the chief binding constraint for pan bread flours. This indicates that the final cost of the blended flour could be reduced given the opportunity for lower priced, lower quality wheats to enter. Some level of high quality wheat in the flour must be maintained to achieve the quality specifications however.

In the average market situation, HWS is able to be used in the flour blend for pan breads at a maximum price premium over the market price for high quality wheats of US$2.69/mt. At this price, HWS would comprise 52.8% of the flour blend. HRS substitutes most closely with high quality red wheats in each simulation. Parametrically decreasing the price of HWS in each simulation first caused HWS to substitute for high quality red wheats such as DNS, and subsequently for standard quality wheats such as HWO and 3CWRS. Usage of HWS can be increased with slight discounts to the market price of high quality wheat as HWS usage is highly elastic around this price level. HWS usage is maximized for pan bread flour at a level of 83.8% share of the flour, however, at this rate the price of HWS would be at a significant discount to that of high quality red wheats. The model demonstrates that HWS shows strong potential for inclusion into flour blends for the domestic pan bread industry, and can achieve significant shares of the flour blend at slight premiums to red wheats. The amount of HWS usage will be at the expense of similar quality red wheats.

For the purpose of the study, flours with high protein and strength requirements such as buns and rolls were described as "specialty" bread products. High quality HWS appears to be well suited for application in this flour, as its inherent high protein content, high gluten content and extraction advantage make it an advantageous option.

Specialty flours must maintain a high level of high quality wheat in the blend to satisfy its quality specifications. The demand for high quality wheat in this blend is therefore relatively inelastic. This is evident in the results of the model, which demonstrate that high quality wheat dominates the flour blend in each market situation. In any given market situation, high quality wheats maintain an 80-95% share of the flour blend for specialty flours.

Analysis of the simulation results indicate that at the market price for high quality wheat, HWS would comprise between 30-50% of the flour blend. As well, the model demonstrates that HWS could achieve a premium of US$4.63/mt over the market price of high quality red wheat and maintain a significant share of the flour blend.

Protein content and LN are the most commonly binding characteristics in the specialty flour blend. As expected, costs could be reduced significantly given the chance for lower quality wheats to enter the blend, however, the demanding protein requirements do not allow for large amounts of this wheat to be included. The general increased susceptibility of white wheats to sustain sprouting damage leads to usage limitation in the blend in order to satisfy LN specifications. Given that enhanced sprouting resistance are being bred into the new lines of HWS, this factor will be less of a concern.

From the results of the analysis, HWS appears to have beneficial attributes for usage in high protein specialty flours. Given price equivalency to the market price for high quality red wheat, HWS would achieve a significant share of the market for this type of product. As well, HWS may be able to realize a small premium over comparable red wheats for usage in this application.

9.3 Export Markets

The model indicates that flour suitable to producing Japanese-style noodles would comprise mainly of wheats from Australian origin. ASW and APH figure largely in the blend as flour properties derived from these wheats are well suited to Japanese-style noodles. ASW appears to be the standard by which other wheats need to compete for usage in Japanese noodle blends, as its share of the blend is largest in all market situations. In addition to having well suited flour characteristics, Australian wheat enjoys a freight advantage over wheat originating from Canada, destined to the Asian market. This allows for Australian white wheats to gain a price advantage and increase its share of imports into South East Asia.

The model determines that a Canadian grown HWS would find a maximum share of the blend at only 5.3% in all market situations, and to do so, it would be at a price discount to the market price for high quality wheat. Protein content is the main limiting factor for HWS acceptance in the blend for Japanese-style noodles. Protein levels anticipated for the new HWS varieties would be too high for flour able to an optimal Japanese noodle, which requires protein in the 9.0-10.5% range. Farinograph stability level is the other limiting flour attribute. Correlated with protein levels, high quality wheats tend to have high stability levels, resulting in "tougher" end products. Japanese-style noodles generally require weaker wheats and therefore limits the amount of high quality HWS able to be included in the blend. High quality Canadian HWS would therefore not likely be well suited to this market beyond a supplemental wheat for blending purposes.

One important attribute required for Japenese-style noodles is the starch swelling characteristic. The model may not accurately reflect this quality requirement as no measure for starch swelling is included. The model does however include Farinograph absorption as a quality characteristic. This measure assesses the amount starch damage of the flour which in turn is correlated to water uptake, however, not direct measure of starch swelling is not included.

Compared to Japanese-style noodles, Chinese-style noodles are made from higher protein flours, resulting in a texturally firmer and stronger end product. This characteristic allows for a greater level of high quality wheats to be included in the flour blend for Chinese-style noodles. Chinese noodles typically have a protein content of between 10.5-12.0%. The model demonstrates that when price premiums for high quality wheat are low, high quality wheat could comprise a large share of the flour blend. The model indicated that under each market condition, HWS share of the flour blend would be maximized at 38.5%. However, HWS would have to be priced significantly below the domestic price for high quality wheat for this to occur. When HWS is priced equivalent to the market price for high quality wheat (assumed by the price of DNS), little to no HWS enters the flour blend for Chinese noodles. The model suggests that, in the market situation where premiums paid for high quality wheat are relatively small, HWS can achieve significant shares of the flour blend at slight discounts to the market price of high quality wheat. When the average market situation prevails, a US$6.35/mt discount to

DNS would allow HWS to comprise 29.9% of the flour blend for Chinese noodles. As the premium for high quality wheat is increased, HWS must take larger price reductions in relation to the market price of high quality wheat, in order to enter the flour blend. As demonstrated by the model, when the price differential between high and low quality wheat is large, HWS must be at a price discount of US$44.25/mt in order to enter the flour blend. The quality characteristics of Chinese noodles is such that large portions of lower quality wheats can be used in the blend to achieve a suitable end product. This factor makes lower priced, lower quality wheats very competitive and diminishes the opportunity for high quality HWS to enter the flour blend at a premium price.

When the price of HWS is parametrically reduced in each simulation, HWS substitutes most directly with other high quality wheats. Price reductions of high quality HWS allow for the substitution of high quality red wheats (DNS) and high quality white wheat (APH) in the blends.

Farinograph stability level is the main binding constraint in the simulations for Chinese style noodles. This is attributed to the large shares of lower quality wheat allowed in the blend. Protein level becomes a factor when HWS levels are increased in the blend and the tolerance for protein content becomes maximized. Flour color is also a factor when large amouts of red wheats are included in the blend, however, this becomes less of a concern when the HWS share increases.

As with the Japanese flour blend, hard white wheats of Australian origin play a large role in the composition of Chinese noodles. APH and ASW have ideal quality properties to produce flour for Chinese style noodles, and also have a freight advantage to the market which allow for these wheats to be very competitive to the Asian noodle market. Canadian HWS is more likely to make up a larger portion of this flour type compared to Japanese noodle flour, however, it would likely have to be priced below the market price of high quality wheat to do so.

The flat bread market is large, extending from the Middle East to India. The breads are typically produced from high extraction flours resulting in flours with very high levels of ash. Protein levels for flat breads tend to be intermediate at between 10.5-12.0%. As well, coloration is an important factor in the end product. These factors appear to make HWS a good candidate for usage in flat bread flour blends.

Simulations of the LP indicate that HWS may be able to maintain a small share of flat bread flour blends at a price equal to or greater than the market price of high quality red wheat. The model showed that at the market price of high quality wheat (represented by DNS), HWS would comprise a 21.5% share of the flat bread flour blend when the price differential between high quality and low quality wheat is small, 15.0% at average price differentials, and 8.0% when differentials are large. This can be attributed to high quality wheat being relatively less expensive compared to standard quality wheat when price differentials are small, making high quality wheat less costly to include in the flour blend. Alternatively, when a premium for high quality wheat exists, these types of wheat become more costly to use in the flour. Therefore, in order to minimize costs, more lower quality wheat is used, diminishing the opportunity for high quality HWS to enter the blend at a premium price. This suggests that users of wheat for producing flat breads are able to be discriminating in the their choice of wheats, and can substitute in large share of lower priced wheats when necessary. High quality HWS acceptance in the flour blends for flat breads therefore are dependent on the price relationship between high and lower quality wheats.

Wheat recurrent in the blend for flat bread in each market situation were CPSW, WW, and low quality HWS. The model indicates that lower quality white wheats tend to play a large role in the flour make-up to achieve a suitable flour for flat bread production. Lower quality HWS therefore would likely be best suited to usage in this market.

Protein content level and extraction levels are the characteristics found to be most frequently binding in the simulations.

9.4 Conclusions

In terms of the domestic market, HWS appears to show favorable potential. Hard white spring wheat quality attributes are such that it would sufficiently be able to meet the requirements of the flour specifications for domestically produced pan breads and specialty breads. In addition to this, given sufficient volumes, HWS would be able to achieve a significant share of the wheat market for domestic bread products. The quality characteristics inherent to HWS allow it to compete closely with high quality red wheats.

Everything being equal, HWS would essentially replace similar quality red wheats in flours for pan bread and specialty applications. For this to be true, it is assumed that HWS would have to mirror CWRS in other aspects as well, such as similar volumes produced, and similar segregation requirements. Priced equivalent to the market price of high quality red wheats, HWS would expect to achieve a market share of pan bread flour of around 56%, this is at the expense of similar quality red wheats. Also, HWS would comprise about 50% of specialty bread blends at price equivalency to high quality red wheats.

Significant shares of HWS could be maintained in these flours at a small price premium of between US$1.00/mt to US$6.00/mt to the market price of high quality red wheat, depending on the application and market conditions. The premium derived for HWS is modest; therefore HWS will have to also show excellent agronomic advantages compared to red wheats in order for large-scale acceptance to occur.

In terms of the export market for noodle and flat breads, a high quality HWS is not perfectly suited as the primary wheat for Asian noodles, as these products generally require lower protein levels. As well, lower priced lower quality wheat are competitively priced and utilized by millers of these flours, diminishing the opportunity for HWS to find a premium. This theory is supported by evidence of the predominate wheats imported for usage in Asian noodle production, which are mainly lower protein white wheats of Australian origin. The model suggest that the portion of the Canadian harvest, which is downgraded to lower quality grades and priced accordingly, would be used first by these millers. High quality HWS appears to be better suited to the flat bread market than for Asian noodles, as higher protein levels and high extraction is required. In the flat bread market however, significant shares of lower quality wheat can be substituted into the blend, reducing the likelihood that HWS could command any significant premium or market share in this market. This coupled with the fact that most flat bread millers are extremely price sensitive, would seem to support this notion. Nonetheless, the fact that HWS is able to meet the general requirements of the flat bread flour specifications would be a benefit to Canada, as red wheat exports cannot sufficiently penetrate this market. An HWS export option would allow for an opportunity to access these large markets in a way that was previously not viable. However, in order to successfully penetrate the pan bread flour market, HWS must be priced competitively with lower quality wheats. This would require substantially higher yields of HWS relative to CWRS before Canadian farmers would choose to grow these varieties.

It should be noted that there is also a large export market for high quality wheat used in levened breads. By no means is the scope of the export market for HWS captured by noodles and flat breads alone. Noodles and flat breads were employed as representative of potential new target markets or potential growth markets for export. HWS may in fact be well suited to the export market primarily as a source of wheat for levened breads. HWS would likely be favored over high quality red wheat, because a high quality white wheat could also be employed in secondary applications, such as noodles and flat breads more readily than a red wheat.

9.5 Limitations of the analysis

The LP model representation of choice for blending wheats to meet certain flour standards, while theoretically beneficial, has the following limitations attached to it.

With the exception of small-scale trial harvest data, the quality characteristics of HWS are largely unknown. Quality results from large-scale field conditions will not be available until such time in the future that enough seed is produced to allow for large-scale seeding of HWS. In general, small isolated plots do not allow for a wide sample to be gathered, and therefore, not reflective of the average quality conditions experienced across the prairies. Hard white wheat quality data was therefore assumed based on its parent CRWS characteristics in combination with HWS trial results for extraction.

Wheat quality characteristics vary from year to year and are highly dependent on growing conditions experienced during the growing year. Quality results used in the study were therefore based on average results from 1984-1997 to represent typical harvest properties. In reality, quality issues are more complex and average quality measures will not always prevail for all wheats.

Quality characteristics must be additive in nature for usage in the LP. Some potentially valuable quality characteristics cannot be used due to their measures not being additive in nature. Fortunately, most of the commonly specified measures, such as protein content and gluten content are additive, therefore appropriate for usage in the model.

Some flour quality attributes are not specified for all kinds of wheat or between origin countries. Therefore, these measures were mostly excluded from usage in the model. Where no data existed, the attribute was excluded from the model, or expert opinion was used as an estimate.

Other conditions not specified in the model may prevent some millers from choosing the least cost combination of wheats determined by the model. For example, additional costs associated with re-calibration of equipment to mill new types of wheat, or long term contracts requiring usage of certain wheats may be reasons why a miller would not necessarily opt for the least cost blend as identified by the model. As well, importing countries do not necessarily choose wheat based on the least cost. For example, some countries buy high quality wheat regardless of the premium associated with it, while others are more price sensitive, purchasing mainly lower quality, lower priced wheats, and only considering high quality wheat when the price premium to lower quality wheat is narrow.

The blend of wheats in the optimal solution represent the lowest cost, however, a number of nearly optimal blends exist that are within a small percentage of the least cost. These blends are not identified and represent potential choices for millers, since the penalty of not being the lowest cost flour grist is not too costly.

The model assumes a large-scale commercial production of HWS, where consistent quality and supply are prevalent. Premiums for HWS as determined by the model exist in the circumstance of large-scale production where no special binning or identity preserved segregation is required. Special handling and segregation of HWS would incur a cost, which may negate the value of any premium it commands in the marketplace. Small-scale start-up production of HWS would likely require several years of special binning or identity preservation.

The model also assumes that for the export market, noodles and flat breads are the primary end product. In reality, levened breads may be better suited as the primary end product for export markets. While red wheats are suitable for levened breads in export markets, it has limited capability to cross over to other applications such as noodles and flat breads. The advantage of HWS relative to red wheats would be evident in that it would be more likely to be chosen as a bread wheat if it had more freedom to be applied to secondary applications such as noodles and flat breads.

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Appendices

Appendix 1.1 Pan Bread Flour Minimum Price Differential

HWS-4.30-3.08-0.66-6.78-1.53-5.74

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	25.101	194.5338	1E+30	25.10061
2CWRS 12.5%	0.000	16.888	186.323	1E+30	16.88764
3CWRS	0.000	4.756	174.1911	1E+30	4.756224
CPSW	0.000	7.158	176.5986	1E+30	7.158192
1DNS	0.000	17.838	187.271	1E+30	17.83785
HWOrd	0.000	9.905	179.3433	1E+30	9.905369
WW	0.125	0.000	169.4428	9.551464	0.009572
ASW	0.000	1293.001	1462.443	1E+30	1293.001
APH	0.000	1296.651	1466.085	1E+30	1296.651
Trigo Pan	0.000	1476.035	1645.475	1E+30	1476.035
EU soft	0.000	1402.821	1572.261	1E+30	1402.821
HWS hi qual	0.875	0.000	169.4332	0.009572	1E+30
HWS low qual	0.000	9.992	179.4273	1E+30	9.991867

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.60	0.00	12	0.6	1E+30
stability	8.53	0.00	7.5	1.033082	1E+30
protein	12.60	0.00	12.6	0.416309	0.6
absorption	63.89	0.00	60	3.889566	1E+30
LN	23.62	0.00	24	1E+30	0.382116
stability	8.53	0.00	12	1E+30	3.466918
absorption	63.89	0.00	69	1E+30	5.110434

HWS US$/t
158.0344

HWS-4.30-3.08-0.66-6.78-1.53

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	19.339	194.5338	1E+30	19.33895
2CWRS 12.5%	0.000	12.462	186.323	1E+30	12.46226
3CWRS	0.000	0.003	174.1911	1E+30	0.002756
CPSW	0.000	5.720	176.5986	1E+30	5.719943
1DNS	0.000	12.085	187.271	1E+30	12.08486
HWOrd	0.000	7.014	179.3433	1E+30	7.013709
WW	0.260	0.000	169.4428	0.016033	5124.821
ASW	0.000	1292.756	1462.443	1E+30	1292.756
APH	0.000	1291.181	1466.085	1E+30	1291.181
Trigo Pan	0.000	1474.182	1645.475	1E+30	1474.182
EU soft	0.000	1401.433	1572.261	1E+30	1401.433
HWS hi qual	0.740	0.000	175.1732	0.003327	5.730428
HWS low qual	0.000	5.564	179.4273	1E+30	5.564485

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	1.30	12	0.6	0.14902
stability	7.71	0.00	7.5	0.205535	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.15	0.00	60	2.154547	1E+30
LN	23.07	0.00	24	1E+30	0.932837
stability	7.71	0.00	12	1E+30	4.294465
absorption	62.15	0.00	69	1E+30	6.845453

HWS US$/t
162.6909

HWS-4.30-3.08-0.66-6.78

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	17.831	194.5338	1E+30	17.83052
2CWRS 12.5%	0.000	11.388	186.323	1E+30	11.38832
3CWRS	0.193	0.000	174.1911	1.264284	0.002518
CPSW	0.000	6.676	176.5986	1E+30	6.67638
1DNS	0.000	8.615	187.271	1E+30	8.615046
HWOrd	0.000	5.512	179.3433	1E+30	5.511977
WW	0.227	0.000	169.4428	0.00727	7.356063
ASW	0.000	1288.004	1462.443	1E+30	1288.004
APH	0.000	1285.457	1466.085	1E+30	1285.457
Trigo Pan	0.000	1470.139	1645.475	1E+30	1470.139
EU soft	0.000	1401.268	1572.261	1E+30	1401.268
HWS hi qual	0.579	0.000	176.7032	0.003852	1.526673
HWS low qual	0.000	5.239	179.4273	1E+30	5.239169

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	12	0.005105	0.14902
stability	7.50	1.19	7.5	0.205535	0.007041
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.49	0.00	60	2.486199	1E+30
LN	23.20	0.00	24	1E+30	0.798103
stability	7.50	0.00	12	1E+30	4.5
absorption	62.49	0.00	69	1E+30	6.513801

HWS US$/t
163.9321

HWS-4.30-3.08-0.66

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	11.051	194.5338	1E+30	11.05057
2CWRS 12.5%	0.000	6.260	186.323	1E+30	6.260185
3CWRS	0.200	-4.429	174.1911	4.429229	1E+30
CPSW	0.000	6.234	176.5986	1E+30	6.23385
1DNS	0.000	0.004	187.271	1E+30	0.004022
HWOrd	0.000	1.411	179.3433	1E+30	1.410986
WW	0.225	0.000	169.4428	2.339972	0.014922
ASW	0.000	1283.320	1462.443	1E+30	1283.32
APH	0.000	1274.996	1466.085	1E+30	1274.996
Trigo Pan	0.000	1464.623	1645.475	1E+30	1464.623
EU soft	0.000	1399.822	1572.261	1E+30	1399.822
HWS hi qual	0.575	0.000	183.4832	0.003168	6.776148
HWS low qual	0.000	0.811	179.4273	1E+30	0.811148

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.01	0.00	12	0.005105	1E+30
stability	7.50	2.30	7.5	0.820507	0.007041
protein	12.01	0.00	12.6	1E+30	0.594895
absorption	62.51	0.00	60	2.512321	1E+30
LN	23.21	0.00	24	1E+30	0.788803
stability	7.50	0.00	12	1E+30	4.5
absorption	62.51	0.00	69	1E+30	6.487679

HWS US$/t
169.4323

HWS-4.30-3.08

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	10.379	194.5338	1E+30	10.3788
2CWRS 12.5%	0.000	5.715	186.323	1E+30	5.715472
3CWRS	0.200	-5.405	174.1911	5.405074	1E+30
CPSW	0.000	5.614	176.5986	1E+30	5.613555
1DNS	0.004	0.000	187.271	0.833844	0.026805
HWOrd	0.000	1.327	179.3433	1E+30	1.326687
WW	0.226	0.000	169.4428	0.051973	31.72153
ASW	0.000	1284.883	1462.443	1E+30	1284.883
APH	0.000	1275.815	1466.085	1E+30	1275.815
Trigo Pan	0.000	1465.615	1645.475	1E+30	1465.615
EU soft	0.000	1399.592	1572.261	1E+30	1399.592
HWS hi qual	0.570	0.000	184.1432	0.009749	0.656832
HWS low qual	0.000	0.012	179.4273	1E+30	0.011833

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.71	12	0.005105	0.529622
stability	7.50	1.90	7.5	0.925243	0.007041
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.50	0.00	60	2.495128	1E+30
LN	23.18	0.00	24	1E+30	0.820487
stability	7.50	0.00	12	1E+30	4.5
absorption	62.50	0.00	69	1E+30	6.504872

HWS US$/t
169.9677

HWS-4.30

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	7.244	194.5338	1E+30	7.243583
2CWRS 12.5%	0.000	3.172	186.323	1E+30	3.172456
3CWRS	0.200	-9.971	174.1911	9.971271	1E+30
CPSW	0.000	2.706	176.5986	1E+30	2.705862
1DNS	0.071	0.000	187.271	2.491109	0.007573
HWOrd	0.000	0.940	179.3433	1E+30	0.940378
WW	0.192	0.000	169.4428	1.891801	3.344672
ASW	0.000	1292.225	1462.443	1E+30	1292.225
APH	0.000	1279.679	1466.085	1E+30	1279.679
Trigo Pan	0.000	1470.279	1645.475	1E+30	1470.279
EU soft	0.000	1398.519	1572.261	1E+30	1398.519
HWS hi qual	0.388	0.000	187.2232	0.007556	3.070251
HWS low qual	0.150	-3.727	179.4273	3.726587	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	4.02	12	0.083259	0.360353
stability	7.50	0.00	7.5	0.629532	0.114835
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.47	0.00	60	2.471489	1E+30
LN	22.91	0.00	24	1E+30	1.094802
stability	7.50	0.00	12	1E+30	4.5
absorption	62.47	0.00	69	1E+30	6.528511

HWS US$/t
172.4663

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	7.236	194.5338	1E+30	7.235892
2CWRS 12.5%	0.000	3.166	186.323	1E+30	3.166217
3CWRS	0.200	-9.982	174.1911	9.982472	1E+30
CPSW	0.000	2.699	176.5986	1E+30	2.698729
1DNS	0.457	0.000	187.271	1.86901	4.854292
HWOrd	0.000	0.939	179.3433	1E+30	0.939431
WW	0.193	0.000	169.4428	1.888818	16.2127
ASW	0.000	1292.243	1462.443	1E+30	1292.243
APH	0.000	1279.689	1466.085	1E+30	1279.689
Trigo Pan	0.000	1470.290	1645.475	1E+30	1470.29
EU soft	0.000	1398.517	1572.261	1E+30	1398.517
HWS hi qual	0.000	4.292	191.5232	1E+30	4.292444
HWS low qual	0.150	-3.736	179.4273	3.735758	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	4.03	12	0.6	0.360353
stability	8.13	0.00	7.5	0.629532	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.25	0.00	60	2.254055	1E+30
LN	20.49	0.00	24	1E+30	3.508939
stability	8.13	0.00	12	1E+30	3.870468
absorption	62.25	0.00	69	1E+30	6.745945

HWS US$/t
175.9546

Appendix 1.2 Pan Bread Flour Average Price Differential

HWS-8.77-0.18-0.21-2.06-6.09-2.62-4.25-23.54

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	51.735	229.4114	1E+30	51.73507
2CWRS 12.5%	0.000	43.410	221.0875	1E+30	43.40969
3CWRS	0.000	31.576	209.2531	1E+30	31.57561
CPSW	0.150	-10.548	167.1333	10.54793	1E+30
1DNS	0.000	39.045	216.7211	1E+30	39.0448
HWOrd	0.000	18.388	196.0675	1E+30	18.38792
WW	0.012	0.000	177.6829	37.0555	0.006537
ASW	0.000	1331.536	1509.218	1E+30	1331.536
APH	0.000	1340.207	1517.884	1E+30	1340.207
Trigo Pan	0.000	1492.627	1670.308	1E+30	1492.627
EU soft	0.000	1423.365	1601.047	1E+30	1423.365
HWS hi qual	0.838	0.000	177.6763	0.006537	42.0964
HWS low qual	0.000	18.159	195.8368	1E+30	18.15897

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.60	0.00	12	0.6	1E+30
stability	8.36	0.00	7.5	0.864127	1E+30
protein	12.60	0.00	12.6	0.0535	0.6
absorption	64.44	0.00	60	4.440294	1E+30
LN	23.26	0.00	24	1E+30	0.735219
stability	8.36	0.00	12	1E+30	3.635873
absorption	64.44	0.00	69	1E+30	4.559706

HWS US$/t
164.7215

HWS-8.77-0.18-0.21-2.06-6.09-2.62-4.25

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	28.106	229.4114	1E+30	28.10624
2CWRS 12.5%	0.000	25.261	221.0875	1E+30	25.261
3CWRS	0.000	12.081	209.2531	1E+30	12.08142
CPSW	0.150	-16.446	167.1333	16.44625	1E+30
1DNS	0.000	15.451	216.7211	1E+30	15.4515
HWOrd	0.000	6.529	196.0675	1E+30	6.529087
WW	0.148	0.000	177.6829	0.009092	21.9449
ASW	0.000	1330.533	1509.218	1E+30	1330.533
APH	0.000	1317.771	1517.884	1E+30	1317.771
Trigo Pan	0.000	1485.028	1670.308	1E+30	1485.028
EU soft	0.000	1417.673	1601.047	1E+30	1417.673
HWS hi qual	0.702	0.000	201.2163	0.002696	23.53346
HWS low qual	0.000	0.002	195.8368	1E+30	0.002079

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	5.33	12	0.6	0.026522
stability	7.54	0.00	7.5	0.03658	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.71	0.00	60	2.705275	1E+30
LN	22.71	0.00	24	1E+30	1.28594
stability	7.54	0.00	12	1E+30	4.46342
absorption	62.71	0.00	69	1E+30	6.294725

HWS US$/t
183.8181

HWS-8.77-0.18-0.21-2.06-6.09-2.62

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	23.945	229.4114	1E+30	23.945
2CWRS 12.5%	0.000	22.389	221.0875	1E+30	22.38925
3CWRS	0.000	13.407	209.2531	1E+30	13.40723
CPSW	0.150	-12.376	167.1333	12.37637	1E+30
1DNS	0.000	3.771	216.7211	1E+30	3.770838
HWOrd	0.000	1.587	196.0675	1E+30	1.586653
WW	0.136	0.000	177.6829	0.004495	14.32589
ASW	0.000	1312.388	1509.218	1E+30	1312.388
APH	0.000	1297.374	1517.884	1E+30	1297.374
Trigo Pan	0.000	1470.055	1670.308	1E+30	1470.055
EU soft	0.000	1417.434	1601.047	1E+30	1417.434
HWS hi qual	0.663	0.000	205.4663	0.002385	4.247304
HWS low qual	0.051	0.000	195.8368	3.276034	0.001558

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	12	0.051633	0.026522
stability	7.50	4.56	7.5	0.03658	0.071214
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.71	0.00	60	2.709888	1E+30
LN	22.76	0.00	24	1E+30	1.238751
stability	7.50	0.00	12	1E+30	4.5
absorption	62.71	0.00	69	1E+30	6.290112

HWS US$/t
187.2658

HWS-8.77-0.18-0.21-2.06-6.09

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	21.325	229.4114	1E+30	21.32505
2CWRS 12.5%	0.000	20.408	221.0875	1E+30	20.40769
3CWRS	0.000	11.697	209.2531	1E+30	11.69697
CPSW	0.150	-12.546	167.1333	12.54596	1E+30
1DNS	0.000	0.441	216.7211	1E+30	0.441234
HWOrd	0.000	0.001	196.0675	1E+30	0.001134
WW	0.102	0.000	177.6829	0.002869	1.637271
ASW	0.000	1310.573	1509.218	1E+30	1310.573
APH	0.000	1293.327	1517.884	1E+30	1293.327
Trigo Pan	0.000	1467.920	1670.308	1E+30	1467.92
EU soft	0.000	1416.875	1601.047	1E+30	1416.875
HWS hi qual	0.598	0.000	208.0863	0.001876	2.617615
HWS low qual	0.150	-1.710	195.8368	1.710223	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.05	0.00	12	0.051633	1E+30
stability	7.50	4.99	7.5	0.621167	0.071214
protein	12.05	0.00	12.6	1E+30	0.548367
absorption	62.87	0.00	60	2.868174	1E+30
LN	22.90	0.00	24	1E+30	1.099491
stability	7.50	0.00	12	1E+30	4.5
absorption	62.87	0.00	69	1E+30	6.131826

HWS US$/t
189.3913

HWS-8.77-0.18-0.21-2.06

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	15.097	229.4114	1E+30	15.09734
2CWRS 12.5%	0.000	15.269	221.0875	1E+30	15.26922
3CWRS	0.000	1.349	209.2531	1E+30	1.34916
CPSW	0.150	-19.693	167.1333	19.69326	1E+30
1DNS	0.000	2.462	216.7211	1E+30	2.461675
HWOrd	0.116	0.000	196.0675	0.929267	0.000181
WW	0.056	0.000	177.6829	0.000364	1.869448
ASW	0.000	1329.980	1509.218	1E+30	1329.98
APH	0.000	1305.418	1517.884	1E+30	1305.418
Trigo Pan	0.000	1480.844	1670.308	1E+30	1480.844
EU soft	0.000	1414.539	1601.047	1E+30	1414.539
HWS hi qual	0.528	0.000	214.1763	0.000359	6.088124
HWS low qual	0.150	-9.994	195.8368	9.994026	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	8.26	12	0.051633	0.063283
stability	7.50	0.00	7.5	0.069539	0.071214
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.89	0.00	60	2.885858	1E+30
LN	22.33	0.00	24	1E+30	1.669737
stability	7.50	0.00	12	1E+30	4.5
absorption	62.89	0.00	69	1E+30	6.114142

HWS US$/t
194.3317

HWS-8.77-0.18-0.21

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	13.022	229.4114	1E+30	13.02167
2CWRS 12.5%	0.000	14.160	221.0875	1E+30	14.15988
3CWRS	0.000	0.002	209.2531	1E+30	0.002272
CPSW	0.150	-18.643	167.1333	18.64271	1E+30
1DNS	0.000	0.393	216.7211	1E+30	0.392756
HWOrd	0.229	0.000	196.0675	0.006561	12.34399
WW	0.000	2.091	177.6829	1E+30	2.090966
ASW	0.000	1331.896	1509.218	1E+30	1331.896
APH	0.000	1303.554	1517.884	1E+30	1303.554
Trigo Pan	0.000	1481.596	1670.308	1E+30	1481.596
EU soft	0.000	1415.626	1601.047	1E+30	1415.626
HWS hi qual	0.471	0.000	216.2363	0.003476	2.059641
HWS low qual	0.150	-11.105	195.8368	11.105	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	9.20	12	0.502	0.063283
stability	7.57	0.00	7.5	0.069539	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	63.05	0.00	60	3.048921	1E+30
LN	21.82	0.00	24	1E+30	2.180292
stability	7.57	0.00	12	1E+30	4.430461
absorption	63.05	0.00	69	1E+30	5.951079

HWS US$/t
196.00

HWS-8.77-0.18

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	12.812	229.4114	1E+30	12.81201
2CWRS 12.5%	0.000	14.086	221.0875	1E+30	14.08622
3CWRS	0.055	0.000	209.2531	0.134994	0.00723
CPSW	0.150	-18.318	167.1333	18.31816	1E+30
1DNS	0.000	0.009	216.7211	1E+30	0.009242
HWOrd	0.210	0.000	196.0675	0.021093	0.389757
WW	0.000	2.435	177.6829	1E+30	2.435202
ASW	0.000	1331.799	1509.218	1E+30	1331.799
APH	0.000	1302.990	1517.884	1E+30	1302.99
Trigo Pan	0.000	1481.446	1670.308	1E+30	1481.446
EU soft	0.000	1415.855	1601.047	1E+30	1415.855
HWS hi qual	0.435	0.000	216.4463	0.005023	0.206524
HWS low qual	0.150	-11.112	195.8368	11.11221	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	9.18	12	0.168906	0.063283
stability	7.50	0.11	7.5	0.069539	0.185604
protein	12.00	0.00	12.6	1E+30	0.6
absorption	63.12	0.00	60	3.115204	1E+30
LN	21.94	0.00	24	1E+30	2.057132
stability	7.50	0.00	12	1E+30	4.5
absorption	63.12	0.00	69	1E+30	5.884796

HWS US$/t
196.1732

HWS-8.77

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	12.629	229.4114	1E+30	12.62872
2CWRS 12.5%	0.000	13.950	221.0875	1E+30	13.95011
3CWRS	0.200	-0.252	209.2531	0.251886	1E+30
CPSW	0.150	-18.442	167.1333	18.44248	1E+30
1DNS	0.114	0.000	216.7211	0.321973	0.000976
HWOrd	0.160	0.000	196.0675	1.236558	0.213924
WW	0.000	2.488	177.6829	1E+30	2.487639
ASW	0.000	1332.256	1509.218	1E+30	1332.256
APH	0.000	1303.198	1517.884	1E+30	1303.198
Trigo Pan	0.000	1481.737	1670.308	1E+30	1481.737
EU soft	0.000	1415.833	1601.047	1E+30	1415.833
HWS hi qual	0.226	0.000	216.6263	0.000972	0.174977
HWS low qual	0.150	-11.315	195.8368	11.31467	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	9.38	12	0.168906	0.199328
stability	7.50	0.00	7.5	0.366668	0.185604
protein	12.00	0.00	12.6	1E+30	0.6
absorption	63.23	0.00	60	3.22887	1E+30
LN	21.56	0.00	24	1E+30	2.441287
stability	7.50	0.00	12	1E+30	4.5
absorption	63.23	0.00	69	1E+30	5.77113

HWS US$/t
196.3193

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	12.628	229.4114	1E+30	12.62773
2CWRS 12.5%	0.000	13.949	221.0875	1E+30	13.94936
3CWRS	0.200	-0.253	209.2531	0.253285	1E+30
CPSW	0.150	-18.443	167.1333	18.44321	1E+30
1DNS	0.339	0.000	216.7211	8.809039	0.389263
HWOrd	0.161	0.000	196.0675	1.237385	0.725076
WW	0.000	2.488	177.6829	1E+30	2.487884
ASW	0.000	1332.259	1509.218	1E+30	1332.259
APH	0.000	1303.200	1517.884	1E+30	1303.2
Trigo Pan	0.000	1481.739	1670.308	1E+30	1481.739
EU soft	0.000	1415.833	1601.047	1E+30	1415.833
HWS hi qual	0.000	8.769	225.3963	1E+30	8.769028
HWS low qual	0.150	-11.316	195.8368	11.3158	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	9.38	12	0.355182	0.199328
stability	7.87	0.00	7.5	0.366668	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	63.10	0.00	60	3.103923	1E+30
LN	20.15	0.00	24	1E+30	3.849601
stability	7.87	0.00	12	1E+30	4.133332
absorption	63.10	0.00	69	1E+30	5.896077

HWS US$/t
203.4338

Appendix 1.3 Pan Bread Flour Maximum Price Differential

HWS-0.37-2.42-15.98-55.26-4.98-1.80-3.52-19.51

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1363.803	1507.402	1E+30	1363.803
2CWRS 12.5%	0.000	83.045	226.6449	1E+30	83.04501
3CWRS	0.000	71.258	214.858	1E+30	71.25836
CPSW	0.150	-20.729	122.8735	20.72871	1E+30
1DNS	0.000	103.883	247.4816	1E+30	103.8828
HWOrd	0.000	15.018	158.6194	1E+30	15.01832
WW	0.012	0.000	143.6033	30.26507	0.00443
ASW	0.000	1305.948	1449.551	1E+30	1305.948
APH	0.000	1396.947	1540.546	1E+30	1396.947
Trigo Pan	0.000	1477.956	1621.558	1E+30	1477.956
EU soft	0.000	1362.833	1506.435	1E+30	1362.833
HWS hi qual	0.838	0.000	143.5989	0.00443	82.72753
HWS low qual	0.000	15.051	158.6513	1E+30	15.05145

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.60	0.00	12	0.6	1E+30
stability	8.36	0.00	7.5	0.864127	1E+30
protein	12.60	0.00	12.6	0.0535	0.6
absorption	64.44	0.00	60	4.440294	1E+30
LN	23.26	0.00	24	1E+30	0.735219
stability	8.36	0.00	12	1E+30	3.635873
absorption	64.44	0.00	69	1E+30	4.559706

HWS US$/t
137.22

HWS-0.37-2.42-15.98-55.26-4.98-1.80-3.52

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1344.219	1507.402	1E+30	1344.219
2CWRS 12.5%	0.000	68.003	226.6449	1E+30	68.00333
3CWRS	0.000	55.102	214.858	1E+30	55.10154
CPSW	0.150	-25.617	122.8735	25.61725	1E+30
1DNS	0.000	84.329	247.4816	1E+30	84.32863
HWOrd	0.000	5.190	158.6194	1E+30	5.189702
WW	0.148	0.000	143.6033	0.013019	34.18214
ASW	0.000	1305.117	1449.551	1E+30	1305.117
APH	0.000	1378.352	1540.546	1E+30	1378.352
Trigo Pan	0.000	1471.659	1621.558	1E+30	1471.659
EU soft	0.000	1358.115	1506.435	1E+30	1358.115
HWS hi qual	0.702	0.000	163.1089	0.00386	19.50557
HWS low qual	0.000	0.003	158.6513	1E+30	0.002977

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	4.42	12	0.6	0.026522
stability	7.54	0.00	7.5	0.03658	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.71	0.00	60	2.705275	1E+30
LN	22.71	0.00	24	1E+30	1.28594
stability	7.54	0.00	12	1E+30	4.46342
absorption	62.71	0.00	69	1E+30	6.294725

HWS US$/t
153.09

HWS-0.37-2.42-15.98-55.26-4.98-1.80

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1340.773	1507.402	1E+30	1340.773
2CWRS 12.5%	0.000	65.625	226.6449	1E+30	65.62469
3CWRS	0.000	56.198	214.858	1E+30	56.19776
CPSW	0.150	-22.248	122.8735	22.2484	1E+30
1DNS	0.000	74.657	247.4816	1E+30	74.65714
HWOrd	0.000	1.097	158.6194	1E+30	1.097278
WW	0.136	0.000	143.6033	0.012219	11.85972
ASW	0.000	1290.096	1449.551	1E+30	1290.096
APH	0.000	1361.465	1540.546	1E+30	1361.465
Trigo Pan	0.000	1459.262	1621.558	1E+30	1459.262
EU soft	0.000	1357.917	1506.435	1E+30	1357.917
HWS hi qual	0.663	0.000	166.6289	0.006483	3.51614
HWS low qual	0.051	0.000	158.6513	2.712072	0.004236

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.01	12	0.051633	0.026522
stability	7.50	3.77	7.5	0.03658	0.071214
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.71	0.00	60	2.709888	1E+30
LN	22.76	0.00	24	1E+30	1.238751
stability	7.50	0.00	12	1E+30	4.5
absorption	62.71	0.00	69	1E+30	6.290112

HWS US$/t
155.96

HWS-0.37-2.42-15.98-55.26-4.98

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1338.973	1507.402	1E+30	1338.973
2CWRS 12.5%	0.000	64.264	226.6449	1E+30	64.26371
3CWRS	0.000	55.027	214.858	1E+30	55.02746
CPSW	0.150	-22.360	122.8735	22.35995	1E+30
1DNS	0.000	72.362	247.4816	1E+30	72.36246
HWOrd	0.000	0.005	158.6194	1E+30	0.005283
WW	0.102	0.000	143.6033	0.013364	3.380362
ASW	0.000	1288.832	1449.551	1E+30	1288.832
APH	0.000	1358.669	1540.546	1E+30	1358.669
Trigo Pan	0.000	1457.782	1621.558	1E+30	1457.782
EU soft	0.000	1357.534	1506.435	1E+30	1357.534
HWS hi qual	0.598	0.000	168.4289	0.008738	1.793517
HWS low qual	0.150	-1.172	158.6513	1.171797	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.05	0.00	12	0.051633	1E+30
stability	7.50	4.08	7.5	0.621167	0.071214
protein	12.05	0.00	12.6	1E+30	0.548367
absorption	62.87	0.00	60	2.868174	1E+30
LN	22.90	0.00	24	1E+30	1.099491
stability	7.50	0.00	12	1E+30	4.5
absorption	62.87	0.00	69	1E+30	6.131826

HWS US$/t
157.42

HWS-0.37-2.42-15.98-55.26

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1333.881	1507.402	1E+30	1333.881
2CWRS 12.5%	0.000	60.062	226.6449	1E+30	60.06244
3CWRS	0.000	46.573	214.858	1E+30	46.57324
CPSW	0.150	-28.197	122.8735	28.19655	1E+30
1DNS	0.000	74.003	247.4816	1E+30	74.0031
HWOrd	0.116	0.000	158.6194	3.005879	0.000834
WW	0.056	0.000	143.6033	0.001681	7.603107
ASW	0.000	1304.673	1449.551	1E+30	1304.673
APH	0.000	1368.530	1540.546	1E+30	1368.53
Trigo Pan	0.000	1468.330	1621.558	1E+30	1468.33
EU soft	0.000	1355.624	1506.435	1E+30	1355.624
HWS hi qual	0.528	0.000	173.4089	0.001656	4.971262
HWS low qual	0.150	-7.941	158.6513	7.940651	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	6.75	12	0.051633	0.063283
stability	7.50	0.00	7.5	0.069539	0.071214
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.89	0.00	60	2.885858	1E+30
LN	22.33	0.00	24	1E+30	1.669737
stability	7.50	0.00	12	1E+30	4.5
absorption	62.89	0.00	69	1E+30	6.114142

HWS US$/t
161.48

HWS-0.37-2.42-15.98

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1278.200	1507.402	1E+30	1278.2
2CWRS 12.5%	0.000	30.307	226.6449	1E+30	30.30655
3CWRS	0.000	10.451	214.858	1E+30	10.45099
CPSW	0.150	-0.002	122.8735	0.002036	1E+30
1DNS	0.000	18.493	247.4816	1E+30	18.49318
HWOrd	0.229	0.000	158.6194	27.83769	0.001348
WW	0.000	56.099	143.6033	1E+30	56.09878
ASW	0.000	1356.035	1449.551	1E+30	1356.035
APH	0.000	1318.498	1540.546	1E+30	1318.498
Trigo Pan	0.000	1488.487	1621.558	1E+30	1488.487
EU soft	0.000	1384.795	1506.435	1E+30	1384.795
HWS hi qual	0.471	0.000	228.6689	0.00399	55.25834
HWS low qual	0.150	-37.736	158.6513	37.73619	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	31.96	12	0.502	0.063283
stability	7.57	0.00	7.5	0.069539	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	63.05	0.00	60	3.048921	1E+30
LN	21.82	0.00	24	1E+30	2.180292
stability	7.57	0.00	12	1E+30	4.430461
absorption	63.05	0.00	69	1E+30	5.951079

HWS US$/t
206.45

HWS-0.37-2.42

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1262.099	1507.402	1E+30	1262.099
2CWRS 12.5%	0.000	21.702	226.6449	1E+30	21.70193
3CWRS	0.000	0.006	214.858	1E+30	0.005711
CPSW	0.000	8.152	122.8735	1E+30	8.152017
1DNS	0.000	2.440	247.4816	1E+30	2.440267
HWOrd	0.456	0.000	158.6194	0.016488	100.5824
WW	0.000	72.322	143.6033	1E+30	72.32182
ASW	0.000	1370.887	1449.551	1E+30	1370.887
APH	0.000	1304.028	1540.546	1E+30	1304.028
Trigo Pan	0.000	1494.315	1621.558	1E+30	1494.315
EU soft	0.000	1393.231	1506.435	1E+30	1393.231
HWS hi qual	0.394	0.000	244.6489	0.008736	15.97601
HWS low qual	0.150	-46.352	158.6513	46.35202	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	39.25	12	0.6	0.343725
stability	7.88	0.00	7.5	0.377706	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.82	0.00	60	2.824631	1E+30
LN	21.15	0.00	24	1E+30	2.849277
stability	7.88	0.00	12	1E+30	4.122294
absorption	62.82	0.00	69	1E+30	6.175369

HWS US$/t
219.45

HWS-0.37

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1259.660	1507.402	1E+30	1259.66
2CWRS 12.5%	0.000	20.399	226.6449	1E+30	20.39886
3CWRS	0.200	-1.576	214.858	1.576115	1E+30
CPSW	0.000	9.387	122.8735	1E+30	9.386861
1DNS	0.000	0.009	247.4816	1E+30	0.009225
HWOrd	0.386	0.000	158.6194	6.215369	2.021746
WW	0.000	74.779	143.6033	1E+30	74.77862
ASW	0.000	1373.136	1449.551	1E+30	1373.136
APH	0.000	1301.837	1540.546	1E+30	1301.837
Trigo Pan	0.000	1495.197	1621.558	1E+30	1495.197
EU soft	0.000	1394.509	1506.435	1E+30	1394.509
HWS hi qual	0.264	0.000	247.0689	0.009183	2.411264
HWS low qual	0.150	-47.657	158.6513	47.65679	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	40.36	12	0.6	0.111536
stability	7.62	0.00	7.5	0.122563	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	63.07	0.00	60	3.067826	1E+30
LN	21.60	0.00	24	1E+30	2.397397
stability	7.62	0.00	12	1E+30	4.377437
absorption	63.07	0.00	69	1E+30	5.932174

HWS US$/t
221.42

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1259.651	1507.402	1E+30	1259.651
2CWRS 12.5%	0.000	20.394	226.6449	1E+30	20.39391
3CWRS	0.200	-1.582	214.858	1.582117	1E+30
CPSW	0.000	9.392	122.8735	1E+30	9.391547
1DNS	0.262	0.000	247.4816	0.362464	2.43149
HWOrd	0.388	0.000	158.6194	6.228029	4.529106
WW	0.000	74.788	143.6033	1E+30	74.78795
ASW	0.000	1373.144	1449.551	1E+30	1373.144
APH	0.000	1301.829	1540.546	1E+30	1301.829
Trigo Pan	0.000	1495.201	1621.558	1E+30	1495.201
EU soft	0.000	1394.514	1506.435	1E+30	1394.514
HWS hi qual	0.000	0.361	247.4389	1E+30	0.360817
HWS low qual	0.150	-47.662	158.6513	47.66175	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	40.36	12	0.6	0.299312
stability	8.05	0.00	7.5	0.550589	1E+30
protein	12.00	0.00	12.6	1E+30	0.6
absorption	62.92	0.00	60	2.92197	1E+30
LN	19.96	0.00	24	1E+30	4.041379
stability	8.05	0.00	12	1E+30	3.949411
absorption	62.92	0.00	69	1E+30	6.07803

HWS US$/t
221.72

Appendix 2.1 Specialty Bread Flour Minimum Price Differential

HWS-4.33-4.0-0.20-5.88

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	6.700	194.53377	1E+30	6.6999198
2CWRS 12.5%	0.000	4.222	186.32303	1E+30	4.2223943
3CWRS	0.000	0.004	174.19106	1E+30	0.0039774
CPSW	0.000	3.364	176.59856	1E+30	3.3638942
1DNS	0.427	0.000	187.27103	6.3454453	0.0110256
HWOrd	0.070	0.000	179.34331	0.0115386	2235.093
WW	0.000	2.609	169.44277	1E+30	2.609316
ASW	0.000	1289.216	1462.4429	1E+30	1289.2159
APH	0.000	1274.883	1466.0851	1E+30	1274.8827
Trigo Pan	0.000	1472.625	1645.4748	1E+30	1472.6251
EU soft	0.000	1409.264	1572.261	1E+30	1409.2641
HWS hi qual	0.502	0.000	177.0832	0.0039146	126.23282
HWS low qual	0.000	6.197	179.42725	1E+30	6.1974405

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	3.82	13	0.1550096	0.2068008
stability	9.82	0.00	9	0.823623	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.91	0.00	64.5	0.407428	1E+30
LN	21.00	-1.63	21	2.6762432	3.1317775
stability	9.82	0.00	12	1E+30	2.176377

HWS US$/t
164.24034

HWS-4.33-4.0-0.20

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	7.012	194.5338	1E+30	7.012006
2CWRS 12.5%	0.000	3.358	186.323	1E+30	3.358185
3CWRS	0.200	-5.970	174.1911	5.970312	1E+30
CPSW	0.000	2.158	176.5986	1E+30	2.158115
1DNS	0.499	0.000	187.271	6.64102	0.002734
HWOrd	0.001	0.000	179.3433	0.001976	17.31995
WW	0.000	0.004	169.4428	1E+30	0.003968
ASW	0.000	1289.921	1462.443	1E+30	1289.921
APH	0.000	1277.613	1466.085	1E+30	1277.613
Trigo Pan	0.000	1470.531	1645.475	1E+30	1470.531
EU soft	0.000	1402.209	1572.261	1E+30	1402.209
HWS hi qual	0.299	0.000	182.9632	0.008956	5.876085
HWS low qual	0.000	0.192	179.4273	1E+30	0.191984

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	3.69	13	0.003191	0.309892
stability	9.69	0.00	9	0.686131	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	65.11	0.00	64.5	0.610532	1E+30
LN	21.00	-0.69	21	1.989363	1.864835
stability	9.69	0.00	12	1E+30	2.313869

HWS US$/t
169.0104

HWS-4.33-4.03

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	7.023	194.5338	1E+30	7.02250383
2CWRS 12.5%	0.000	3.348	186.323	1E+30	3.34831573
3CWRS	0.200	-6.159	174.1911	6.158992	1E+30
CPSW	0.000	2.181	176.5986	1E+30	2.18061279
1DNS	0.500	0.000	187.271	0.058311	0.04744779
HWOrd	0.000	0.042	179.3433	1E+30	0.04214352
WW	0.001	0.000	169.4428	0.030858	35.8880214
ASW	0.000	1290.027	1462.443	1E+30	1290.02662
APH	0.000	1277.710	1466.085	1E+30	1277.70979
Trigo Pan	0.000	1470.517	1645.475	1E+30	1470.5172
EU soft	0.000	1402.033	1572.261	1E+30	1402.03327
HWS hi qual	0.299	0.000	183.1632	0.007658	0.19104371
HWS low qual	0.000	0.007	179.4273	1E+30	0.00704616

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	3.71	13	0.003191	0.21639323
stability	9.69	0.00	9	0.686946	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	65.11	0.00	64.5	0.607855	1E+30
LN	21.00	-0.65	21	1.989363	1.86097757
stability	9.69	0.00	12	1E+30	2.31305428

HWS US$/t
169.1727

HWS-4.33

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	7.211	194.5338	1E+30	7.211432
2CWRS 12.5%	0.000	6.907	186.323	1E+30	6.906786
3CWRS	0.200	-7.165	174.1911	7.16544	1E+30
CPSW	0.000	14.855	176.5986	1E+30	14.85532
1DNS	0.501	0.000	187.271	6.848813	0.00094
HWOrd	0.000	9.001	179.3433	1E+30	9.000979
WW	0.000	16.209	169.4428	1E+30	16.20895
ASW	0.000	1307.762	1462.443	1E+30	1307.762
APH	0.000	1280.483	1466.085	1E+30	1280.483
Trigo Pan	0.000	1481.279	1645.475	1E+30	1481.279
EU soft	0.000	1410.816	1572.261	1E+30	1410.816
HWS hi qual	0.296	0.000	187.1932	0.000931	4.022342
HWS low qual	0.003	0.000	179.4273	3.7012	0.094927

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	7.69	13	0.003191	0.148309
stability	9.69	0.00	9	0.685439	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	65.11	0.00	64.5	0.607877	1E+30
LN	21.00	0.00	21	1.989363	1.826243
stability	9.69	0.00	12	1E+30	2.314561

HWS US$/t
172.442

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	7.211	194.5338	1E+30	7.211476
2CWRS 12.5%	0.000	6.908	186.323	1E+30	6.907609
3CWRS	0.200	-7.166	174.1911	7.165671	1E+30
CPSW	0.000	14.858	176.5986	1E+30	14.85825
1DNS	0.794	0.000	187.271	4.371931	4.854292
HWOrd	0.000	9.003	179.3433	1E+30	9.003051
WW	0.000	16.213	169.4428	1E+30	16.2127
ASW	0.000	1307.766	1462.443	1E+30	1307.766
APH	0.000	1280.484	1466.085	1E+30	1280.484
Trigo Pan	0.000	1481.281	1645.475	1E+30	1481.281
EU soft	0.000	1410.818	1572.261	1E+30	1410.818
HWS hi qual	0.000	4.329	191.5232	1E+30	4.329069
HWS low qual	0.006	0.000	179.4273	3.735758	9.503408

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	7.69	13	0.006182	0.146818
stability	10.16	0.00	9	1.160283	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.94	0.00	64.5	0.443414	1E+30
LN	19.17	0.00	21	1E+30	1.826243
stability	10.16	0.00	12	1E+30	1.839717

HWS US$/t
175.9546

Appendix 2.2 Specialty Bread Flour Average Price Differential

HWS-8.83-5.89-83.99

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	7.854	229.4114	1E+30	7.85403
2CWRS 12.5%	0.000	27.168	221.0875	1E+30	27.16838
3CWRS	0.000	91.130	209.2531	1E+30	91.12995
CPSW	0.000	0.000	167.1333	1E+30	0.00049
1DNS	0.427	0.000	216.7211	7.438495	0.000689
HWOrd	0.070	0.000	196.0675	0.000325	2818.158
WW	0.000	42.339	177.6829	1E+30	42.3395
ASW	0.000	1321.467	1509.218	1E+30	1321.467
APH	0.000	1261.442	1517.884	1E+30	1261.442
Trigo Pan	0.000	1513.770	1670.308	1E+30	1513.77
EU soft	0.000	1523.746	1601.047	1E+30	1523.746
HWS hi qual	0.502	0.000	126.6863	0.002391	147.9773
HWS low qual	0.000	80.544	195.8368	1E+30	80.54416

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	11.28	13	0.15501	0.206801
stability	9.82	0.00	9	0.823623	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.91	0.00	64.5	0.407428	1E+30
LN	21.00	-14.43	21	2.676243	3.131778
stability	9.82	0.00	12	1E+30	2.176377

HWS US$/t
123.36

HWS-8.83-5.89

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	12.280	229.4114	1E+30	12.28002
2CWRS 12.5%	0.000	20.119	221.0875	1E+30	20.11899
3CWRS	0.000	9.733	209.2531	1E+30	9.732587
CPSW	0.047	0.000	167.1333	0.01238	1957.279
1DNS	0.461	0.000	216.7211	11.64484	0.014311
HWOrd	0.000	11.428	196.0675	1E+30	11.42846
WW	0.000	28.080	177.6829	1E+30	28.07971
ASW	0.000	1353.553	1509.218	1E+30	1353.553
APH	0.000	1301.588	1517.884	1E+30	1301.588
Trigo Pan	0.000	1499.417	1670.308	1E+30	1499.417
EU soft	0.000	1440.345	1601.047	1E+30	1440.345
HWS hi qual	0.493	0.000	210.6763	0.003929	83.98761
HWS low qual	0.000	0.004	195.8368	1E+30	0.003768

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	14.70	13	0.15501	0.279952
stability	9.78	0.00	9	0.7819	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.96	0.00	64.5	0.458788	1E+30
LN	21.00	-0.95	21	2.878353	3.070162
stability	9.78	0.00	12	1E+30	2.2181

HWS US$/t
191.49

HWS-8.83

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	12.590	229.4114	1E+30	12.59041
2CWRS 12.5%	0.000	19.625	221.0875	1E+30	19.62465
3CWRS	0.000	4.024	209.2531	1E+30	4.02441
CPSW	0.001	0.000	167.1333	17.59421	1.799374
1DNS	0.500	0.000	216.7211	11.93917	0.005436
HWOrd	0.000	12.230	196.0675	1E+30	12.22993
WW	0.000	27.080	177.6829	1E+30	27.07976
ASW	0.000	1355.803	1509.218	1E+30	1355.803
APH	0.000	1304.403	1517.884	1E+30	1304.403
Trigo Pan	0.000	1498.411	1670.308	1E+30	1498.411
EU soft	0.000	1434.496	1601.047	1E+30	1434.496
HWS hi qual	0.349	0.000	216.5663	0.00542	5.886071
HWS low qual	0.150	-5.644	195.8368	5.64431	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	14.94	13	0.00351	0.172422
stability	9.79	0.00	9	0.78981	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.78	0.00	64.5	0.282568	1E+30
LN	21.00	0.00	21	2.187699	2.173918
stability	9.79	0.00	12	1E+30	2.21019

HWS US$/t
196.27

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	12.591	229.4114	1E+30	12.59069
2CWRS 12.5%	0.000	19.624	221.0875	1E+30	19.6242
3CWRS	0.000	4.019	209.2531	1E+30	4.019157
CPSW	0.002	0.000	167.1333	17.34984	18.38859
1DNS	0.848	0.000	216.7211	5.23092	8.154941
HWOrd	0.000	12.231	196.0675	1E+30	12.23067
WW	0.000	27.079	177.6829	1E+30	27.07884
ASW	0.000	1355.805	1509.218	1E+30	1355.805
APH	0.000	1304.406	1517.884	1E+30	1304.406
Trigo Pan	0.000	1498.410	1670.308	1E+30	1498.41
EU soft	0.000	1434.491	1601.047	1E+30	1434.491
HWS hi qual	0.000	8.825	225.3963	1E+30	8.82458
HWS low qual	0.150	-5.650	195.8368	5.649507	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	14.94	13	0.007	0.056204
stability	10.35	0.00	9	1.354871	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.59	0.00	64.5	0.090851	1E+30
LN	18.83	0.00	21	1E+30	2.173918
stability	10.35	0.00	12	1E+30	1.645129

HWS US$/t
203.43

Appendix 2.3 Specialty Bread Flour Maximum Price Differential

HWS-4.85-1.53-44.68

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1257.197	1507.402	1E+30	1257.197
2CWRS 12.5%	0.000	27.190	226.6449	1E+30	27.19003
3CWRS	0.000	45.400	214.858	1E+30	45.39955
CPSW	0.000	18.874	122.8735	1E+30	18.87377
1DNS	0.427	0.000	247.4816	69.7701	0.014371
HWOrd	0.070	0.000	158.6194	0.015039	10180.55
WW	0.000	95.276	143.6033	1E+30	95.27634
ASW	0.000	1367.596	1449.551	1E+30	1367.596
APH	0.000	1280.361	1540.546	1E+30	1280.361
Trigo Pan	0.000	1511.669	1621.558	1E+30	1511.669
EU soft	0.000	1449.994	1506.435	1E+30	1449.994
HWS hi qual	0.502	0.000	200.8379	0.006754	2757.75
HWS low qual	0.000	0.007	159.0932	1E+30	0.006898

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	41.34	13	0.15501	0.206801
stability	9.82	0.00	9	0.823623	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.91	0.00	64.5	0.407428	1E+30
LN	21.00	-7.42	21	2.676243	3.131778
stability	9.82	0.00	12	1E+30	2.176377

HWS US$/t
183.51

HWS-4.85-1.53

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1259.568	1507.402	1E+30	1259.568
2CWRS 12.5%	0.000	20.623	226.6449	1E+30	20.62322
3CWRS	0.000	0.003	214.858	1E+30	0.00308
CPSW	0.000	9.711	122.8735	1E+30	9.711484
1DNS	0.499	0.000	247.4816	52.91953	0.008538
HWOrd	0.002	0.000	158.6194	0.008935	99.48054
WW	0.000	75.479	143.6033	1E+30	75.47924
ASW	0.000	1372.957	1449.551	1E+30	1372.957
APH	0.000	1301.104	1540.546	1E+30	1301.104
Trigo Pan	0.000	1495.756	1621.558	1E+30	1495.756
EU soft	0.000	1396.386	1506.435	1E+30	1396.386
HWS hi qual	0.349	0.000	245.5179	0.003031	44.67325
HWS low qual	0.150	-45.626	159.0932	45.6264	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	40.39	13	0.00351	0.142835
stability	9.79	0.00	9	0.790755	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.78	0.00	64.5	0.281405	1E+30
LN	21.00	-0.25	21	2.187699	2.176614
stability	9.79	0.00	12	1E+30	2.209245

HWS US$/t
219.76

HWS-4.85

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1259.637	1507.402	1E+30	1259.637
2CWRS 12.5%	0.000	22.484	226.6449	1E+30	22.48364
3CWRS	0.005	0.000	214.858	1.551454	0.738882
CPSW	0.000	16.181	122.8735	1E+30	16.1805
1DNS	0.501	0.000	247.4816	4.30072	0.009734
HWOrd	0.000	4.501	158.6194	1E+30	4.500788
WW	0.000	83.842	143.6033	1E+30	83.84153
ASW	0.000	1381.808	1449.551	1E+30	1381.808
APH	0.000	1302.268	1540.546	1E+30	1302.268
Trigo Pan	0.000	1501.339	1621.558	1E+30	1501.339
EU soft	0.000	1401.391	1506.435	1E+30	1401.391
HWS hi qual	0.344	0.000	247.0479	0.009607	1.526969
HWS low qual	0.150	-45.125	159.0932	45.12477	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	42.41	13	0.00351	0.148309
stability	9.79	0.00	9	0.787576	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.79	0.00	64.5	0.2861	1E+30
LN	21.00	0.00	21	2.187699	2.118958
stability	9.79	0.00	12	1E+30	2.212424

HWS US$/t
221.00

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	1259.637	1507.402	1E+30	1259.637
2CWRS 12.5%	0.000	22.495	226.6449	1E+30	22.49535
3CWRS	0.009	0.000	214.858	1.582117	34.02217
CPSW	0.000	16.221	122.8735	1E+30	16.22121
1DNS	0.841	0.000	247.4816	4.904158	2.43149
HWOrd	0.000	4.529	158.6194	1E+30	4.529106
WW	0.000	83.894	143.6033	1E+30	83.89416
ASW	0.000	1381.863	1449.551	1E+30	1381.863
APH	0.000	1302.275	1540.546	1E+30	1302.275
Trigo Pan	0.000	1501.374	1621.558	1E+30	1501.374
EU soft	0.000	1401.423	1506.435	1E+30	1401.423
HWS hi qual	0.000	4.840	251.8979	1E+30	4.840393
HWS low qual	0.150	-45.122	159.0932	45.1216	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	13.00	42.42	13	0.007	0.146818
stability	10.34	0.00	9	1.336188	1E+30
protein	13.00	0.00	14.5	1E+30	1.5
absorption	64.60	0.00	64.5	0.102652	1E+30
LN	18.88	0.00	21	1E+30	2.118958
stability	10.34	0.00	12	1E+30	1.663812

HWS US$/t
224.93

Appendix 3.1 Japanese Noodle Flour Minimum Price Differential

HWS-21.33

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	25.546	231.1876	1E+30	25.54571
2CWRS 12.5%	0.000	21.664	223.2961	1E+30	21.66355
3CWRS	0.000	12.361	211.1113	1E+30	12.36053
CPSW	0.000	23.870	213.0633	1E+30	23.86982
1DNS	0.000	12.645	224.7078	1E+30	12.64469
HWOrd	0.000	15.571	215.6431	1E+30	15.57128
WW	0.000	14.729	204.2817	1E+30	14.72917
ASW	0.610	0.000	205.6243	0.003848	7.545307
APH	0.337	0.000	218.9147	26.20291	0.003327
Trigo Pan	0.000	13.817	220.222	1E+30	13.81739
EU soft	0.000	0.003	192.7778	1E+30	0.00323
HWS hi qual	0.053	0.000	205.6708	0.002855	1E+30
HWS low qual	0.000	15.790	214.9692	1E+30	15.79008

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	0.00	9	1.5	1E+30
stability	9.25	3.90	9.25	0.187937	1.14382
protein	10.50	-1.74	10.5	0.642496	0.145574
stability	9.25	0.00	15	1E+30	5.75
LN	16.44	0.00	25	1E+30	8.564969
colour	80.83	0.00	80	0.825066	1E+30
absorption	60.88	0.00	62	1E+30	1.123535
absorption	60.88	0.00	57	3.876465	1E+30

HWS US$/t
159.1493

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	25.543	231.1876	1E+30	25.54284
2CWRS 12.5%	0.000	21.661	223.2961	1E+30	21.66055
3CWRS	0.000	12.357	211.1113	1E+30	12.35677
CPSW	0.000	23.866	213.0633	1E+30	23.86583
1DNS	0.000	12.643	224.7078	1E+30	12.64314
HWOrd	0.000	15.569	215.6431	1E+30	15.56876
WW	0.000	14.726	204.2817	1E+30	14.72601
ASW	0.571	0.000	205.6243	26.15962	3.479255
APH	0.382	0.000	218.9147	9.70792	56.35549
Trigo Pan	0.000	13.817	220.222	1E+30	13.81671
EU soft	0.047	0.000	192.7778	5.422723	1E+30
HWS hi qual	0.000	21.327	227.0008	1E+30	21.32714
HWS low qual	0.000	15.787	214.9692	1E+30	15.78658

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	0.00	9	1.5	1E+30
stability	9.25	3.90	9.25	0.187937	2.689261
protein	10.50	-1.73	10.5	1.145482	0.145574
stability	9.25	0.00	15	1E+30	5.75
LN	16.35	0.00	25	1E+30	8.646699
colour	80.79	0.00	80	0.786472	1E+30
absorption	60.49	0.00	62	1E+30	1.505442
absorption	60.49	0.00	57	3.494558	1E+30

HWS US$/t
175.9546

Appendix 3.2 Japanese Noodle Flour Average Price Differential

HWS-45.88

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	51.401	267.1311	1E+30	51.40148
2CWRS 12.5%	0.000	50.636	259.1331	1E+30	50.63556
3CWRS	0.000	52.883	247.2641	1E+30	52.88335
CPSW	0.000	25.270	203.3109	1E+30	25.27033
1DNS	0.000	12.904	255.0893	1E+30	12.90439
HWOrd	0.000	20.187	232.8839	1E+30	20.1865
WW	0.000	23.298	212.7693	1E+30	23.29819
ASW	0.610	0.000	253.8445	0.001021	70.12138
APH	0.337	0.000	272.3025	0.012425	19.20451
Trigo Pan	0.000	0.001	245.9203	1E+30	0.000719
EU soft	0.000	29.409	222.5181	1E+30	29.4094
HWS hi qual	0.053	0.000	215.9985	0.003026	1E+30
HWS low qual	0.000	33.470	231.8683	1E+30	33.46958

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	0.00	9	1.5	1E+30
stability	9.25	16.05	9.25	0.187937	1.14382
protein	10.50	-16.13	10.5	0.642496	0.145574
stability	9.25	0.00	15	1E+30	5.75
LN	16.44	0.00	25	1E+30	8.564969
colour	80.83	0.00	80	0.825066	1E+30
absorption	60.88	0.00	62	1E+30	1.123535
absorption	60.88	0.00	57	3.876465	1E+30

HWS US$/t
167.2861

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	51.398	267.1311	1E+30	51.39844
2CWRS 12.5%	0.000	50.632	259.1331	1E+30	50.63239
3CWRS	0.000	52.879	247.2641	1E+30	52.87936
CPSW	0.000	25.266	203.3109	1E+30	25.2661
1DNS	0.000	12.903	255.0893	1E+30	12.90274
HWOrd	0.000	20.184	232.8839	1E+30	20.18383
WW	0.000	23.295	212.7693	1E+30	23.29484
ASW	0.454	0.000	253.8445	1E+30	7.656582
APH	0.324	0.000	272.3025	36.84346	15.7043
Trigo Pan	0.222	0.000	245.9203	4.295846	1E+30
EU soft	0.000	29.406	222.5181	1E+30	29.40598
HWS hi qual	0.000	45.877	261.8785	1E+30	45.87697
HWS low qual	0.000	33.466	231.8683	1E+30	33.46587

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	0.00	9	1.5	1E+30
stability	9.25	16.05	9.25	0.187937	0.338419
protein	10.50	-16.13	10.5	0.228334	0.145574
stability	9.25	0.00	15	1E+30	5.75
LN	16.75	0.00	25	1E+30	8.24718
colour	80.53	0.00	80	0.52838	1E+30
absorption	60.55	0.00	62	1E+30	1.448564
absorption	60.55	0.00	57	3.551436	1E+30

HWS US$/t
203.4338

Appendix 3.3 Japanese Noodle Flour Maximum Price Differential

HWS-90.27

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	96.089	276.1523	1E+30	96.08945
2CWRS 12.5%	0.000	116.511	264.8619	1E+30	116.5112
3CWRS	0.000	130.388	253.0434	1E+30	130.3878
CPSW	0.000	110.353	157.708	1E+30	110.3529
1DNS	0.000	51.132	286.8226	1E+30	51.13248
HWOrd	0.000	55.991	194.2789	1E+30	55.99061
WW	0.000	123.963	177.6661	1E+30	123.963
ASW	0.610	0.000	192.3346	0.003024	78.0653
APH	0.337	0.000	295.6605	0.036802	47.68051
Trigo Pan	0.000	0.002	195.4721	1E+30	0.00213
EU soft	0.000	46.289	124.7687	1E+30	46.28863
HWS hi qual	0.053	0.000	180.3621	0.008964	1E+30
HWS low qual	0.000	66.929	194.0286	1E+30	66.92892

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	0.00	9	1.5	1E+30
stability	9.25	33.81	9.25	0.187937	1.14382
protein	10.50	-17.96	10.5	0.642496	0.145574
stability	9.25	0.00	15	1E+30	5.75
LN	16.44	0.00	25	1E+30	8.564969
colour	80.83	0.00	80	0.825066	1E+30
absorption	60.88	0.00	62	1E+30	1.123535
absorption	60.88	0.00	57	3.876465	1E+30

HWS US$/t
139.21

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	96.080	276.1523	1E+30	96.08043
2CWRS 12.5%	0.000	116.502	264.8619	1E+30	116.5018
3CWRS	0.000	130.376	253.0434	1E+30	130.376
CPSW	0.000	110.340	157.708	1E+30	110.3403
1DNS	0.000	51.128	286.8226	1E+30	51.12761
HWOrd	0.000	55.983	194.2789	1E+30	55.98271
WW	0.000	123.953	177.6661	1E+30	123.9531
ASW	0.454	0.000	192.3346	1E+30	13.77987
APH	0.324	0.000	295.6605	145.9936	37.13072
Trigo Pan	0.222	0.000	195.4721	9.720412	1E+30
EU soft	0.000	46.278	124.7687	1E+30	46.27848
HWS hi qual	0.000	90.261	270.6321	1E+30	90.26104
HWS low qual	0.000	66.918	194.0286	1E+30	66.91793

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	0.00	9	1.5	1E+30
stability	9.25	33.81	9.25	0.187937	0.338419
protein	10.50	-17.95	10.5	0.228334	0.145574
stability	9.25	0.00	15	1E+30	5.75
LN	16.75	0.00	25	1E+30	8.24718
colour	80.53	0.00	80	0.52838	1E+30
absorption	60.55	0.00	62	1E+30	1.448564
absorption	60.55	0.00	57	3.551436	1E+30

HWS US$/t
210.33

Appendix 4.1 Chinese Noodle Flour Minimum Price Differential

HWS-18.39-2.60

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	24.939	226.5509	1E+30	24.93931
2CWRS 12.5%	0.000	21.160	218.8783	1E+30	21.1596
3CWRS	0.000	12.189	207.0647	1E+30	12.18941
CPSW	0.000	23.449	209.0495	1E+30	23.44941
1DNS	0.000	12.213	220.1351	1E+30	12.21319
HWOrd	0.000	15.234	211.4732	1E+30	15.23431
WW	0.000	14.587	200.5907	1E+30	14.58724
ASW	0.254	0.000	201.7883	0.005242	7.613201
APH	0.360	0.000	214.6647	25.30873	0.004533
Trigo Pan	0.000	12.870	215.3684	1E+30	12.86991
EU soft	0.000	0.004	189.1253	1E+30	0.0044
HWS hi qual	0.385	0.000	201.6408	0.00389	1E+30
HWS low qual	0.000	15.653	210.9602	1E+30	15.65255

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	10.00	3.84	10	1.374438	1.22279
protein	12.00	-1.75	12	1.105538	1.06463
stability	10.00	0.00	15	1E+30	5
LN	18.91	0.00	25	1E+30	6.094933
colour	80.40	0.00	79.5	0.898022	1E+30

HWS US$/t
158.87

HWS-18.39

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	22.310	226.5509	1E+30	22.31021
2CWRS 12.5%	0.000	19.319	218.8783	1E+30	19.31887
3CWRS	0.000	9.483	207.0647	1E+30	9.483445
CPSW	0.000	22.767	209.0495	1E+30	22.76704
1DNS	0.000	10.709	220.1351	1E+30	10.70928
HWOrd	0.000	14.827	211.4732	1E+30	14.82674
WW	0.000	15.565	200.5907	1E+30	15.56546
ASW	0.000	3.499	201.7883	1E+30	3.498721
APH	0.655	0.000	214.6647	3.025393	0.013919
Trigo Pan	0.000	14.717	215.3684	1E+30	14.7169
EU soft	0.303	0.000	189.1253	2.937076	0.020211
HWS hi qual	0.043	0.000	204.2408	0.008243	2.59611
HWS low qual	0.000	13.383	210.9602	1E+30	13.38337

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	10.00	3.16	10	0.163137	2.353888
protein	12.00	-0.01	12	1.105538	0.063337
stability	10.00	0.00	15	1E+30	5
LN	18.37	0.00	25	1E+30	6.626631
colour	80.15	0.00	79.5	0.646952	1E+30

HWS US$/t
160.99

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	22.302	226.5509	1E+30	22.30188
2CWRS 12.5%	0.000	19.313	218.8783	1E+30	19.31304
3CWRS	0.000	9.475	207.0647	1E+30	9.47487
CPSW	0.000	22.765	209.0495	1E+30	22.76489
1DNS	0.000	10.705	220.1351	1E+30	10.70451
HWOrd	0.000	14.825	211.4732	1E+30	14.82546
WW	0.000	15.569	200.5907	1E+30	15.56858
ASW	0.000	3.510	201.7883	1E+30	3.50983
APH	0.680	0.000	214.6647	9.793232	25.53943
Trigo Pan	0.000	14.723	215.3684	1E+30	14.72277
EU soft	0.320	0.000	189.1253	5.470377	1E+30
HWS hi qual	0.000	18.382	222.6308	1E+30	18.38176
HWS low qual	0.000	13.376	210.9602	1E+30	13.37618

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	11.94	0.00	10.5	1.436663	1E+30
stability	10.00	3.16	10	0.163137	3.700432
protein	11.94	0.00	12	1E+30	0.063337
stability	10.00	0.00	15	1E+30	5
LN	18.16	0.00	25	1E+30	6.843413
colour	80.15	0.00	79.5	0.650051	1E+30

HWS US$/t
175.95

Appendix 4.2 Chinese Noodle Flour Average Price Differential

HWS-21.67-0.33-24.98

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	52.474	261.314	1E+30	52.4744
2CWRS 12.5%	0.000	51.810	253.5275	1E+30	51.8102
3CWRS	0.000	54.670	242.0095	1E+30	54.66994
CPSW	0.000	28.320	199.6152	1E+30	28.3197
1DNS	0.000	13.799	249.4852	1E+30	13.79948
HWOrd	0.000	21.915	228.1418	1E+30	21.91453
WW	0.000	25.677	208.8042	1E+30	25.67709
ASW	0.254	0.000	248.4087	0.003086	72.06824
APH	0.360	0.000	266.2925	0.037565	21.16542
Trigo Pan	0.000	0.002	240.1089	1E+30	0.002174
EU soft	0.000	31.215	217.8087	1E+30	31.21513
HWS hi qual	0.385	0.000	209.1159	0.00915	1E+30
HWS low qual	0.000	35.848	227.3172	1E+30	35.84769

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	10.00	16.29	10	1.374438	1.22279
protein	12.00	-16.58	12	1.105538	1.06463
stability	10.00	0.00	15	1E+30	5
LN	18.91	0.00	25	1E+30	6.094933
colour	80.40	0.00	79.5	0.898022	1E+30

HWS US$/t
164.96

HWS-21.67-0.33

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	27.311	261.314	1E+30	27.31144
2CWRS 12.5%	0.000	27.724	253.5275	1E+30	27.72354
3CWRS	0.000	23.506	242.0095	1E+30	23.50566
CPSW	0.000	0.513	199.6152	1E+30	0.512514
1DNS	0.000	0.005	249.4852	1E+30	0.00543
HWOrd	0.000	4.422	228.1418	1E+30	4.422412
WW	0.000	7.266	208.8042	1E+30	7.265941
ASW	0.000	8.423	248.4087	1E+30	8.422752
APH	0.340	0.000	266.2925	0.011202	0.391086
Trigo Pan	0.361	0.000	240.1089	0.428017	0.147095
EU soft	0.000	10.025	217.8087	1E+30	10.02499
HWS hi qual	0.299	0.000	234.0959	0.009832	24.97085
HWS low qual	0.000	7.425	227.3172	1E+30	7.425221

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	10.00	9.41	10	1.087325	1.147291
protein	12.00	-5.60	12	1.105538	0.681489
stability	10.00	0.00	15	1E+30	5
LN	19.42	0.00	25	1E+30	5.577499
colour	79.91	0.00	79.5	0.414949	1E+30

HWS US$/t
185.29

HWS-21.67

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	27.021	261.314	1E+30	27.0207
2CWRS 12.5%	0.000	27.416	253.5275	1E+30	27.41569
3CWRS	0.000	23.110	242.0095	1E+30	23.11026
CPSW	0.000	0.012	199.6152	1E+30	0.011718
1DNS	0.408	0.000	249.4852	0.176799	0.015521
HWOrd	0.000	4.211	228.1418	1E+30	4.211466
WW	0.000	6.858	208.8042	1E+30	6.857658
ASW	0.000	8.204	248.4087	1E+30	8.204217
APH	0.142	0.000	266.2925	9.979184	0.012406
Trigo Pan	0.376	0.000	240.1089	0.010019	17.09861
EU soft	0.000	9.612	217.8087	1E+30	9.612109
HWS hi qual	0.074	0.000	234.4259	0.007659	0.320168
HWS low qual	0.000	7.018	227.3172	1E+30	7.017829

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	10.00	9.31	10	0.265033	0.487735
protein	12.00	-5.48	12	0.749044	0.211397
stability	10.00	0.00	15	1E+30	5
LN	18.62	0.00	25	1E+30	6.375393
colour	79.50	0.17	79.5	0.414949	0.137282

HWS US$/t
185.55

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	27.014	261.314	1E+30	27.01398
2CWRS 12.5%	0.000	27.409	253.5275	1E+30	27.40855
3CWRS	0.000	23.101	242.0095	1E+30	23.10109
CPSW	0.049	0.000	199.6152	8.364635	0.50157
1DNS	0.444	0.000	249.4852	0.248834	5.380855
HWOrd	0.000	4.207	228.1418	1E+30	4.206585
WW	0.000	6.848	208.8042	1E+30	6.848064
ASW	0.000	8.199	248.4087	1E+30	8.19891
APH	0.188	0.000	266.2925	6.559595	0.219265
Trigo Pan	0.319	0.000	240.1089	0.394372	9.290427
EU soft	0.000	9.602	217.8087	1E+30	9.602432
HWS hi qual	0.000	21.962	256.3959	1E+30	21.96234
HWS low qual	0.000	7.008	227.3172	1E+30	7.008351

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	10.00	9.31	10	0.265033	1.596901
protein	12.00	-5.48	12	0.540937	0.211397
stability	10.00	0.00	15	1E+30	5
LN	17.96	0.00	25	1E+30	7.036799
colour	79.50	0.18	79.5	0.621792	0.137282

HWS US$/t
203.43

Appendix 4.3 Chinese Noodle Flour Maximum Price Differential

HWS-48.31-41.02

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	94.799	270.0389	1E+30	94.79903
2CWRS 12.5%	0.000	114.580	259.0665	1E+30	114.5797
3CWRS	0.000	128.448	247.5957	1E+30	128.4475
CPSW	0.000	109.332	155.4997	1E+30	109.3322
1DNS	0.000	50.255	280.1413	1E+30	50.25514
HWOrd	0.000	55.758	190.818	1E+30	55.7585
WW	0.000	122.003	174.8347	1E+30	122.0028
ASW	0.254	0.000	188.9395	0.001533	78.36936
APH	0.360	0.000	288.8803	0.018661	48.18256
Trigo Pan	0.000	0.001	191.541	1E+30	0.00108
EU soft	0.000	46.776	123.5331	1E+30	46.77602
HWS hi qual	0.385	0.000	175.5403	0.004545	1E+30
HWS low qual	0.000	67.080	190.6914	1E+30	67.08045

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	10.00	33.21	10	1.374438	1.22279
protein	12.00	-18.03	12	1.105538	1.06463
stability	10.00	0.00	15	1E+30	5
LN	18.91	0.00	25	1E+30	6.094933
colour	80.40	0.00	79.5	0.898022	1E+30

HWS US$/t
137.63

HWS-48.31

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	53.479	270.0389	1E+30	53.47858
2CWRS 12.5%	0.000	75.028	259.0665	1E+30	75.02754
3CWRS	0.000	77.273	247.5957	1E+30	77.27294
CPSW	0.000	63.673	155.4997	1E+30	63.67258
1DNS	0.000	27.604	280.1413	1E+30	27.60364
HWOrd	0.000	27.036	190.818	1E+30	27.03635
WW	0.000	91.773	174.8347	1E+30	91.77349
ASW	0.000	13.835	188.9395	1E+30	13.83465
APH	0.340	0.000	288.8803	56.9494	0.001462
Trigo Pan	0.361	0.000	191.541	9.746419	0.000506
EU soft	0.000	11.982	123.5331	1E+30	11.98237
HWS hi qual	0.299	0.000	216.5603	0.000376	41.01545
HWS low qual	0.000	20.408	190.6914	1E+30	20.40846

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	10.00	21.92	10	1.087325	1.147291
protein	12.00	0.00	12	1.105538	0.681489
stability	10.00	0.00	15	1E+30	5
LN	19.42	0.00	25	1E+30	5.577499
colour	79.91	0.00	79.5	0.414949	1E+30

HWS US$/t
171.01

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	53.478	270.0389	1E+30	53.4782
2CWRS 12.5%	0.000	75.027	259.0665	1E+30	75.02717
3CWRS	0.000	77.272	247.5957	1E+30	77.27248
CPSW	0.000	63.672	155.4997	1E+30	63.67216
1DNS	0.000	27.603	280.1413	1E+30	27.60344
HWOrd	0.000	27.036	190.818	1E+30	27.03609
WW	0.000	91.773	174.8347	1E+30	91.77321
ASW	0.000	13.835	188.9395	1E+30	13.83478
APH	0.417	0.000	288.8803	44.0498	14.5809
Trigo Pan	0.583	0.000	191.541	6.577172	1E+30
EU soft	0.000	11.982	123.5331	1E+30	11.98205
HWS hi qual	0.000	48.310	264.8703	1E+30	48.30962
HWS low qual	0.000	20.408	190.6914	1E+30	20.40803

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	11.32	0.00	10.5	0.818511	1E+30
stability	10.00	21.92	10	1.087325	1.305947
protein	11.32	0.00	12	1E+30	0.681489
stability	10.00	0.00	15	1E+30	5
LN	17.74	0.00	25	1E+30	7.263296
colour	79.81	0.00	79.5	0.30528	1E+30

HWS US$/t
210.33

Appendix 5.1 Flat Bread Flour Minimum Price Differential

HWS-3.49-2.33-1.16-0.68-9.86-45.48

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	66.665	207.8231	1E+30	66.66459
2CWRS 12.5%	0.000	49.799	201.1895	1E+30	49.79892
3CWRS	0.000	42.001	190.8796	1E+30	42.00119
CPSW	0.000	18.590	192.8533	1E+30	18.58965
1DNS	0.000	60.369	201.5936	1E+30	60.36876
HWOrd	0.000	31.347	194.482	1E+30	31.34736
WW	0.260	0.000	185.2766	0.002047	43.95231
ASW	0.000	2.960	186.3646	1E+30	2.95983
APH	0.000	54.172	197.5581	1E+30	54.17244
Trigo Pan	0.000	25.234	196.323	1E+30	25.23395
EU soft	0.000	0.002	174.65	1E+30	0.001552
HWS hi qual	0.740	0.000	141.3243	0.006419	1E+30
HWS low qual	0.000	42.865	194.2402	1E+30	42.86494

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	7.71	0.00	3	4.705535	1E+30
protein	12.00	-9.95	12	0.213497	1.436715
stability	7.71	0.00	8	1E+30	0.294465
LN	23.07	0.00	30	1E+30	6.932837
colour	80.14	0.00	79.5	0.639353	1E+30
absorption	62.15	0.00	65	1E+30	2.845453
absorption	62.15	0.00	58	4.154547	1E+30
extraction	90.64	0.00	88	2.644443	1E+30

HWS US$/t
116.47

HWS-3.49-2.33-1.16-0.68-9.86

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	24.859	207.8231	1E+30	24.85914
2CWRS 12.5%	0.000	19.354	201.1895	1E+30	19.35417
3CWRS	0.000	9.903	190.8796	1E+30	9.902879
CPSW	0.000	9.182	192.8533	1E+30	9.181641
1DNS	0.000	21.959	201.5936	1E+30	21.9594
HWOrd	0.000	12.437	194.482	1E+30	12.43659
WW	0.001	0.000	185.2766	6.36887	0.004437
ASW	0.000	4.549	186.3646	1E+30	4.549138
APH	0.000	15.066	197.5581	1E+30	15.0664
Trigo Pan	0.000	26.349	196.323	1E+30	26.34906
EU soft	0.342	0.000	174.65	0.035202	1E+30
HWS hi qual	0.657	0.000	186.8043	0.005077	45.47358
HWS low qual	0.000	8.138	194.2402	1E+30	8.137771

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	7.65	0.00	3	4.646346	1E+30
protein	12.00	0.00	12	0.0041	1.347283
stability	7.65	0.00	8	1E+30	0.353654
LN	24.39	0.00	30	1E+30	5.606159
colour	80.15	0.00	79.5	0.654124	1E+30
absorption	61.86	0.00	65	1E+30	3.140769
absorption	61.86	0.00	58	3.859231	1E+30
extraction	88.00	1.42	88	2.644443	0.010466

HWS US$/t
159.41

HWS-3.49-2.33-1.16-0.68

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	15.577	207.8231	1E+30	15.57727
2CWRS 12.5%	0.000	12.412	201.1895	1E+30	12.41229
3CWRS	0.000	1.324	190.8796	1E+30	1.324357
CPSW	0.000	4.261	192.8533	1E+30	4.261
1DNS	0.000	13.632	201.5936	1E+30	13.6318
HWOrd	0.000	7.016	194.482	1E+30	7.015811
WW	0.338	0.000	185.2766	0.028524	3.311526
ASW	0.000	0.004	186.3646	1E+30	0.00418
APH	0.000	7.979	197.5581	1E+30	7.979435
Trigo Pan	0.000	23.558	196.323	1E+30	23.55847
EU soft	0.300	0.000	174.65	0.010657	68.32355
HWS hi qual	0.362	0.000	196.6643	0.009064	9.854923
HWS low qual	0.000	0.520	194.2402	1E+30	0.519942

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.65	0.00	10.5	0.152717	1E+30
stability	5.80	0.00	3	2.795469	1E+30
protein	10.65	0.00	12	1E+30	1.347283
stability	5.80	0.00	8	1E+30	2.204531
LN	22.99	0.00	30	1E+30	7.007684
colour	80.21	0.00	79.5	0.70676	1E+30
absorption	58.00	0.00	65	1E+30	7
absorption	58.00	0.75	58	3.859231	0.43745
extraction	88.00	1.65	88	2.293939	3.137302

HWS US$/t
168.72

HWS-3.49-2.33-1.16

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	14.951	207.8231	1E+30	14.95097
2CWRS 12.5%	0.000	11.955	201.1895	1E+30	11.95515
3CWRS	0.000	0.835	190.8796	1E+30	0.835187
CPSW	0.000	4.104	192.8533	1E+30	4.10387
1DNS	0.000	13.058	201.5936	1E+30	13.05753
HWOrd	0.000	6.726	194.482	1E+30	6.725521
WW	0.328	0.000	185.2766	0.001077	1.862294
ASW	0.067	0.000	186.3646	0.011322	4.917575
APH	0.000	7.403	197.5581	1E+30	7.402696
Trigo Pan	0.000	23.558	196.323	1E+30	23.55784
EU soft	0.273	0.000	174.65	0.007864	0.788892
HWS hi qual	0.331	0.000	197.3443	0.00027	0.670936
HWS low qual	0.000	0.000	194.2402	1E+30	0.000206

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	0.14	10.5	0.152717	1.579165
stability	5.85	0.00	3	2.854768	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	5.85	0.00	8	1E+30	2.145232
LN	22.50	0.00	30	1E+30	7.496669
colour	80.28	0.00	79.5	0.78109	1E+30
absorption	58.00	0.00	65	1E+30	7
absorption	58.00	0.76	58	2.987001	0.43745
extraction	88.00	1.67	88	2.205552	2.976248

HWS US$/t
169.36

HWS-3.49-2.33

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	13.883	207.8231	1E+30	13.88289
2CWRS 12.5%	0.000	11.176	201.1895	1E+30	11.17582
3CWRS	0.000	0.003	190.8796	1E+30	0.003084
CPSW	0.000	3.840	192.8533	1E+30	3.840027
1DNS	0.000	12.078	201.5936	1E+30	12.07789
HWOrd	0.000	6.232	194.482	1E+30	6.232247
WW	0.300	0.000	185.2766	6.941458	0.006877
ASW	0.065	0.000	186.3646	0.00931	4.958125
APH	0.000	6.417	197.5581	1E+30	6.41682
Trigo Pan	0.000	23.561	196.323	1E+30	23.56118
EU soft	0.269	0.000	174.65	0.007713	2.152829
HWS hi qual	0.216	0.000	198.5043	0.004299	1.15973
HWS low qual	0.150	-0.886	194.2402	0.886272	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	0.37	10.5	0.146522	1.064335
stability	5.74	0.00	3	2.73689	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	5.74	0.00	8	1E+30	2.26311
LN	22.64	0.00	30	1E+30	7.362872
colour	80.27	0.00	79.5	0.771984	1E+30
absorption	58.00	0.00	65	1E+30	7
absorption	58.00	0.76	58	2.725941	0.419706
extraction	88.00	1.70	88	2.173796	2.716128

HWS US$/t
170.46

HWS-3.49

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	11.963	207.8231	1E+30	11.9627
2CWRS 12.5%	0.000	9.962	201.1895	1E+30	9.962294
3CWRS	0.195	0.000	190.8796	1.668296	0.001203
CPSW	0.000	6.277	192.8533	1E+30	6.277338
1DNS	0.000	10.111	201.5936	1E+30	10.11092
HWOrd	0.000	6.602	194.482	1E+30	6.602053
WW	0.387	0.000	185.2766	3.719952	0.005677
ASW	0.000	5.036	186.3646	1E+30	5.035942
APH	0.000	3.004	197.5581	1E+30	3.003908
Trigo Pan	0.000	26.691	196.323	1E+30	26.69149
EU soft	0.191	0.000	174.65	0.002376	4.172156
HWS hi qual	0.077	0.000	200.8343	0.001704	2.325701
HWS low qual	0.150	-2.575	194.2402	2.575168	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	3.07	10.5	0.146522	0.066096
stability	5.29	0.00	3	2.288491	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	5.29	0.00	8	1E+30	2.711509
LN	22.71	0.00	30	1E+30	7.293075
colour	80.15	0.00	79.5	0.649865	1E+30
absorption	58.00	0.00	65	1E+30	7
absorption	58.00	0.00	58	0.233424	0.419706
extraction	88.00	1.86	88	1.854859	1.127377

HWS US$/t
172.66

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	11.961	207.8231	1E+30	11.96129
2CWRS 12.5%	0.000	9.961	201.1895	1E+30	9.961407
3CWRS	0.304	0.000	190.8796	2.461866	2.381313
CPSW	0.000	6.279	192.8533	1E+30	6.279124
1DNS	0.000	10.109	201.5936	1E+30	10.10948
HWOrd	0.000	6.602	194.482	1E+30	6.602325
WW	0.410	0.000	185.2766	7.160764	5.942194
ASW	0.000	5.040	186.3646	1E+30	5.039632
APH	0.000	3.001	197.5581	1E+30	3.00141
Trigo Pan	0.000	26.694	196.323	1E+30	26.69379
EU soft	0.136	0.000	174.65	4.997844	4.864405
HWS hi qual	0.000	3.488	204.3243	1E+30	3.488296
HWS low qual	0.150	-2.576	194.2402	2.576403	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	3.07	10.5	1.087658	0.066096
stability	5.18	0.00	3	2.182701	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	5.18	0.00	8	1E+30	2.817299
LN	22.57	0.00	30	1E+30	7.430409
colour	80.12	0.00	79.5	0.618425	1E+30
absorption	58.23	0.00	65	1E+30	6.766576
absorption	58.23	0.00	58	0.233424	1E+30
extraction	88.00	1.86	88	0.898129	1.127377

HWS US$/t
175.95

Appendix 5.2 Flat Bread Flour Average Price Differential

HWS-6.80-7.92-34.01-22.88

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	76.115	237.8184	1E+30	76.11466
2CWRS 12.5%	0.000	62.271	231.0831	1E+30	62.27111
3CWRS	0.000	53.926	220.993	1E+30	53.92624
CPSW	0.000	0.000	184.7025	1E+30	0.000428
1DNS	0.000	65.012	226.7619	1E+30	65.01209
HWOrd	0.000	31.848	208.8191	1E+30	31.84847
WW	0.260	0.000	192.3528	0.000571	30.5338
ASW	0.000	35.500	226.5527	1E+30	35.50033
APH	0.000	78.851	242.1015	1E+30	78.8505
Trigo Pan	0.000	34.808	217.305	1E+30	34.8084
EU soft	0.000	14.175	199.1448	1E+30	14.17545
HWS hi qual	0.740	0.000	161.819	0.001708	1E+30
HWS low qual	0.000	39.535	208.3362	1E+30	39.53477

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	7.71	0.00	3	4.705535	1E+30
protein	12.00	-6.91	12	0.213497	1.436715
stability	7.71	0.00	8	1E+30	0.294465
LN	23.07	0.00	30	1E+30	6.932837
colour	80.14	0.00	79.5	0.639353	1E+30
absorption	62.15	0.00	65	1E+30	2.845453
absorption	62.15	0.00	58	4.154547	1E+30
extraction	90.64	0.00	88	2.644443	1E+30

HWS US$/t
135.82

HWS-6.80-7.92-34.01

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	53.119	237.8184	1E+30	53.11946
2CWRS 12.5%	0.000	46.383	231.0831	1E+30	46.38312
3CWRS	0.000	36.293	220.993	1E+30	36.29327
CPSW	0.347	0.000	184.7025	5.732523	0.003491
1DNS	0.000	42.063	226.7619	1E+30	42.06296
HWOrd	0.000	24.118	208.8191	1E+30	24.11783
WW	0.000	7.649	192.3528	1E+30	7.649137
ASW	0.000	41.849	226.5527	1E+30	41.8493
APH	0.000	57.402	242.1015	1E+30	57.40233
Trigo Pan	0.000	32.603	217.305	1E+30	32.60289
EU soft	0.000	14.442	199.1448	1E+30	14.44231
HWS hi qual	0.653	0.000	184.699	0.003491	22.87829
HWS low qual	0.000	23.636	208.3362	1E+30	23.63615

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	7.31	0.00	3	4.314199	1E+30
protein	12.00	0.00	12	0.398829	1.5
stability	7.31	0.00	8	1E+30	0.685801
LN	22.25	0.00	30	1E+30	7.750699
colour	80.15	0.00	79.5	0.654899	1E+30
absorption	63.43	0.00	65	1E+30	1.569849
absorption	63.43	0.00	58	5.430151	1E+30
extraction	90.16	0.00	88	2.158912	1E+30

HWS US$/t
157.43

HWS-6.80-7.92

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	18.938	237.8184	1E+30	18.93821
2CWRS 12.5%	0.000	22.767	231.0831	1E+30	22.7666
3CWRS	0.000	10.083	220.993	1E+30	10.08287
CPSW	0.801	0.000	184.7025	0.012532	2631.521
1DNS	0.000	7.950	226.7619	1E+30	7.950214
HWOrd	0.000	12.627	208.8191	1E+30	12.62704
WW	0.000	19.020	192.3528	1E+30	19.02005
ASW	0.000	51.288	226.5527	1E+30	51.28756
APH	0.000	25.521	242.1015	1E+30	25.5207
Trigo Pan	0.000	29.325	217.305	1E+30	29.32508
EU soft	0.000	14.840	199.1448	1E+30	14.83962
HWS hi qual	0.199	0.000	218.709	0.005503	34.00651
HWS low qual	0.000	0.004	208.3362	1E+30	0.003824

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	10.27	10.5	1.5	0.66
stability	4.73	0.00	3	1.734894	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	4.73	0.00	8	1E+30	3.265106
LN	19.81	0.00	30	1E+30	10.19428
colour	80.24	0.00	79.5	0.735822	1E+30
absorption	60.76	0.00	65	1E+30	4.243565
absorption	60.76	0.00	58	2.756435	1E+30
extraction	89.16	0.00	88	1.159668	1E+30

HWS US$/t
189.54

HWS-6.80

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	10.978	237.8184	1E+30	10.97833
2CWRS 12.5%	0.000	17.267	231.0831	1E+30	17.26696
3CWRS	0.000	3.979	220.993	1E+30	3.979185
CPSW	0.755	0.000	184.7025	14.75971	2.080972
1DNS	0.000	0.006	226.7619	1E+30	0.006287
HWOrd	0.000	9.951	208.8191	1E+30	9.951151
WW	0.000	21.668	192.3528	1E+30	21.66803
ASW	0.000	53.485	226.5527	1E+30	53.48547
APH	0.000	18.096	242.1015	1E+30	18.09635
Trigo Pan	0.000	28.562	217.305	1E+30	28.56176
EU soft	0.000	14.932	199.1448	1E+30	14.93214
HWS hi qual	0.095	0.000	226.629	0.006268	7.914497
HWS low qual	0.150	-5.499	208.3362	5.499499	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	12.67	10.5	1.5	0.315
stability	4.68	0.00	3	1.678654	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	4.68	0.00	8	1E+30	3.321346
LN	20.05	0.00	30	1E+30	9.947475
colour	80.23	0.00	79.5	0.727649	1E+30
absorption	60.60	0.00	65	1E+30	4.39802
absorption	60.60	0.00	58	2.60198	1E+30
extraction	89.19	0.00	88	1.186457	1E+30

HWS US$/t
197.01

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	10.972	237.8184	1E+30	10.97203
2CWRS 12.5%	0.000	17.263	231.0831	1E+30	17.26261
3CWRS	0.000	3.974	220.993	1E+30	3.974354
CPSW	0.755	0.000	184.7025	14.7603	17.91451
1DNS	0.095	0.000	226.7619	5.172609	7.944695
HWOrd	0.000	9.949	208.8191	1E+30	9.949033
WW	0.000	21.670	192.3528	1E+30	21.67012
ASW	0.000	53.487	226.5527	1E+30	53.48721
APH	0.000	18.090	242.1015	1E+30	18.09047
Trigo Pan	0.000	28.561	217.305	1E+30	28.56116
EU soft	0.000	14.932	199.1448	1E+30	14.93221
HWS hi qual	0.000	6.794	233.429	1E+30	6.793732
HWS low qual	0.150	-5.504	208.3362	5.503855	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	12.67	10.5	0.828287	0.315
stability	4.83	0.00	3	1.832783	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	4.83	0.00	8	1E+30	3.167217
LN	19.46	0.00	30	1E+30	10.54044
colour	80.13	0.00	79.5	0.632821	1E+30
absorption	60.55	0.00	65	1E+30	4.450313
absorption	60.55	0.00	58	2.549687	1E+30
extraction	88.71	0.00	88	0.707537	1E+30

HWS US$/t
203.43

Appendix 5.3 Flat Bread Flour Maximum Price Differential

HWS-51.83-32.60

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	100.942	245.3467	1E+30	100.9419
2CWRS 12.5%	0.000	94.957	235.8619	1E+30	94.95651
3CWRS	0.000	87.561	225.8069	1E+30	87.56133
CPSW	0.002	0.000	146.5887	7.059948	0.001819
1DNS	0.000	118.962	253.0502	1E+30	118.9622
HWOrd	0.000	35.163	176.716	1E+30	35.16311
WW	0.000	11.529	163.0872	1E+30	11.52876
ASW	0.000	34.454	175.2886	1E+30	34.45351
APH	0.000	118.649	261.5899	1E+30	118.6487
Trigo Pan	0.000	71.966	176.1153	1E+30	71.9663
EU soft	0.342	0.000	118.6363	0.007053	39.05515
HWS hi qual	0.657	0.000	156.3037	0.002452	34.13008
HWS low qual	0.000	22.647	176.7731	1E+30	22.64676

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	12.00	0.00	10.5	1.5	1E+30
stability	7.64	0.00	3	4.644511	1E+30
protein	12.00	0.00	12	0.0041	1.5
stability	7.64	0.00	8	1E+30	0.355489
LN	24.39	0.00	30	1E+30	5.61128
colour	80.15	0.00	79.5	0.654186	1E+30
absorption	61.87	0.00	65	1E+30	3.134354
absorption	61.87	0.00	58	3.865646	1E+30
extraction	88.00	4.41	88	2.158912	0.010466

HWS US$/t
130.62

HWS-51.83

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	68.014	245.3467	1E+30	68.01431
2CWRS 12.5%	0.000	72.149	235.8619	1E+30	72.14906
3CWRS	0.000	62.221	225.8069	1E+30	62.22101
CPSW	0.615	0.000	146.5887	0.014872	27.14104
1DNS	0.000	85.959	253.0502	1E+30	85.9594
HWOrd	0.000	24.035	176.716	1E+30	24.03492
WW	0.000	22.541	163.0872	1E+30	22.54068
ASW	0.000	43.459	175.2886	1E+30	43.45864
APH	0.000	87.914	261.5899	1E+30	87.91434
Trigo Pan	0.000	68.231	176.1153	1E+30	68.231
EU soft	0.184	0.000	118.6363	27.4581	0.175556
HWS hi qual	0.202	0.000	188.9037	0.007146	32.59755
HWS low qual	0.000	0.005	176.7731	1E+30	0.004963

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	9.89	10.5	1.5	0.664389
stability	4.91	0.00	3	1.912322	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	4.91	0.00	8	1E+30	3.087678
LN	20.95	0.00	30	1E+30	9.04508
colour	80.24	0.00	79.5	0.735439	1E+30
absorption	59.92	0.00	65	1E+30	5.083944
absorption	59.92	0.00	58	1.916056	1E+30
extraction	88.00	4.35	88	1.159668	2.644029

HWS US$/t
161.40

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.000	15.663	245.3467	1E+30	15.66347
2CWRS 12.5%	0.000	35.888	235.8619	1E+30	35.88801
3CWRS	0.000	21.933	225.8069	1E+30	21.93302
CPSW	0.565	0.000	146.5887	17.6254	26.54254
1DNS	0.000	33.489	253.0502	1E+30	33.48899
HWOrd	0.000	6.342	176.716	1E+30	6.342458
WW	0.000	40.048	163.0872	1E+30	40.04827
ASW	0.000	57.776	175.2886	1E+30	57.7757
APH	0.000	39.051	261.5899	1E+30	39.0505
Trigo Pan	0.000	62.292	176.1153	1E+30	62.29233
EU soft	0.188	0.000	118.6363	21.22667	135.6686
HWS hi qual	0.097	0.000	240.7337	15.50764	51.82285
HWS low qual	0.150	-35.993	176.7731	35.99272	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	25.61	10.5	1.381643	0.320954
stability	4.86	0.00	3	1.860181	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	4.86	0.00	8	1E+30	3.139819
LN	21.23	0.00	30	1E+30	8.771731
colour	80.23	0.00	79.5	0.727257	1E+30
absorption	59.74	0.00	65	1E+30	5.257812
absorption	59.74	0.00	58	1.742188	1E+30
extraction	88.00	4.25	88	1.186457	2.404103

HWS US$/t
210.33

HWS+15.51

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
1CRWS 13.5%	0.096	0.000	245.3467	0.002386	68.00709
2CWRS 12.5%	0.000	25.039	235.8619	1E+30	25.03863
3CWRS	0.000	9.879	225.8069	1E+30	9.878778
CPSW	0.607	0.000	146.5887	0.005431	26.49652
1DNS	0.000	17.790	253.0502	1E+30	17.78974
HWOrd	0.000	1.049	176.716	1E+30	1.048838
WW	0.000	45.287	163.0872	1E+30	45.28658
ASW	0.000	62.059	175.2886	1E+30	62.05939
APH	0.000	24.430	261.5899	1E+30	24.43035
Trigo Pan	0.000	60.515	176.1153	1E+30	60.51547
EU soft	0.146	0.000	118.6363	6.821611	0.005559
HWS hi qual	0.000	0.002	256.2437	1E+30	0.002362
HWS low qual	0.150	-46.763	176.7731	46.7633	1E+30

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
protein	10.50	30.32	10.5	1.5	0.320954
stability	4.82	0.00	3	1.817435	1E+30
protein	10.50	0.00	12	1E+30	1.5
stability	4.82	0.00	8	1E+30	3.182565
LN	20.33	0.00	30	1E+30	9.665979
colour	80.20	0.00	79.5	0.704556	1E+30
absorption	59.93	0.00	65	1E+30	5.067765
absorption	59.93	0.00	58	1.932235	1E+30
extraction	88.00	4.22	88	0.929744	2.679705

HWS US$/t
224.97