The Relationship Between Grade and Processing Quality Characteristics of Canada Western Red Spring Wheat

by

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

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ABSTRACT

A primary objective of a grading system is to enhance price efficiency. Theoretically, grading systems increase price efficiency by making available to the end-users more information about the good. It has been suggested however, that the Canadian wheat grading system fails to enhance price efficiency because it provides end-users with little information on the criteria that end-users consider important, the processing quality characteristics. Specifically, it is perceived by some that there is an insignificant difference in processing quality characteristics between grades.

The primary objective of this study was to determine whether there exists a significant difference in processing characteristics between grades Nos. 1,2 and 3 C.W.R.S. wheat. The approach taken to fulfill this objective involved obtaining test results on processing quality criteria by grade and applying a statistical test to the data. The statistical test served to group together those test results which exhibited no significant difference. The statistical test used is referred to as a "Duncan's Test".

The results indicated that for no comparisons between two different grades were all processing characteristics significantly different. The comparison of some treatments proved

substantially more similar (e.g. No. 1C.W.R.S. 13.5% vs. No. 2C.W.R.S. 13.5%) than did the comparison between other treatments (e.g. No. 1C.W.R.S. 14.5% vs. No. 3C.W.R.S.). It was concluded that the horizontal orientation of protein content of C.W.R.S. wheat exaggerated certain results. For those comparisons of grades of comparable protein contents, it was concluded that the relationship between protein content and the rheological and bread volume characteristics was partially responsible for the large number of processing characteristics that were shown not to be different. However, the above conclusion did not explain the similarity of the remaining processing characteristics between grades. Finally, it was concluded that an insignificant difference between grades in terms of processing quality characteristics prevents the grading system for C.W.R.S. wheat from enhancing optimal pricing efficiency.

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A number of individuals contributed towards the completion of this study. This acknowledgement recognizes those individuals and represents a gesture of appreciation for their efforts. First and foremost, I would like to thank Dr. W. Bushuk for his guidance, expertise and particularly his patience from the beginning to the completion of this study. I would like to thank Dr. H. Sapirstein for his assistance in processing the data. Thanks to Dr. R.M.A. Loyns, Dr. C.A. Carter and Dr. A. Wilson for their critiques. Thanks to Dr. K.H.Tipples, (Director , Grain Research Laboratory Division, Canadian Grain Commission) for allowing the use of the data taken from the Quarterly Cargo Bulletins. Finally, thanks to my parents, my brother and my sister for their encouragement throughout my formal education.

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Chapter I

INTRODUCTION

The function of a grading system is to segregate the large supply of a heterogeneous good into a small number of homogeneous categories referred to as grades.[1] The desired result is to decrease the variation of quality within a grade relative to the variation between grades. The criteria used to segregate the heterogeneous pool are referred to as grading factors or grading standards. Grades are distinguished on the basis of graduated levels of one or more specified grading standards.

1.1 THE CANADIAN WHEAT GRADING SYSTEM

Wheat is a relatively heterogeneous product before entering the marketing chain largely as a result of its production process. This characteristic makes it a suitable product for the grading process. In Canada, the Canada Grain Act delegates the responsibility for the grading system to the Canadian Grain Commission(C.G.C.). The delegation of the responsibility is stated clearly in section II of the Act which reads "...The Commission shall, in the interests of grain producers, establish and maintain standards of quality for Canadian grain and regulate grain handling in Canada, to

[1] F.W.Williams and T.T.Stout, Economics of the Livestock-Meat Industry (N.Y.N.Y.:The MacMillan Co.,1964),467.

ensure a dependable commodity for domestic and export markets".

The C.G.C. has responded by implementing a vertically oriented grading system for all grains under its jurisdiction (Table 1). Grading systems of vertical orientation are built on the assumption that quality increases from a low level at one end of the scale to a high level at the extreme opposite end.[2] Since quality is generally an indicator of value, price should be directly related to the level of quality and hence grade.

The vertical orientation of the Canada Western Red Spring(CWRS) wheat grades is represented numerically. Samples that meet or surpass the top specifications of the five grade standards (test weight,variety,percentage vitreous kernels,soundness and maximum limits of foreign material) are graded No.1 CWRS. Samples failing to meet one or more of the standards of a higher grade are downgraded to the next lower grade indicated by the next number. For CWRS wheat, three grades, No.1,2 and 3 CWRS, represent the wheat used for human consumption. The fourth grade, Canada Feed, does not have a number and represents wheat that does not meet at least one of the grade standards of grade No.3 CWRS. It is used primarily as livestock feed.

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[2] Ibid.,472.

Table 1 Grades of Canada Western Red Spring Wheat

Standard of Quality					Mamximum Limits of			
					Foreign Material Other Than Wheat		Wheats of Other Classes or Varieties	
Grade Name	Minimum Kilograms per Measured Hectolitre	Variety	Minimum Percentage by Weight of Hard Vitreous Kernels	Degree of Soundness	Matter Other Than Cereal Grains	Total Including Cereal Grains Other Than Wheat	Durum	Total Including Durum
No. 1 Canada Western Red Spring	75	Neepawa or any Variety Equal to Neepawa	65	Reasonably well matured, reasonably free from damaged kernels.	Practically free	About 0.75%	About 1%	About 3%
No. 2 Canada Western Red Spring	72	Neepawa or any Variety Equal to Neepawa	35	Fairly well matured, may be moderately bleached, or frost damaged, but reasonably from severely weather damaged kernels.	Reasonably free	About 1.75%	About 3%	About 6%
No. 3 Canada Western Red Spring	67	Any variety of fair milling quality	—	Excluded from higher grades on account of frosted, immature or otherwise damaged kernels	Reasonably free	About 3.5%	About 5%	10%

(source: Canadian Internaional Grains Institute)

1.2 STATEMENT OF THE PROBLEM

From an economic perspective, the increased homogeneity of grades of wheat resulting from the grading process serves to 1) increase operational efficiency and 2) increase pricing efficiency.[3] McCoy[4] describes operational efficiency as being analogous to an engineer's concept of physical efficiency i.e. it is based on an input-output relationship. The introduction of a wheat grading system may increase the operational efficiency of individual firms in several ways. First, the ability to trade on description reduces the costs associated with inspecting individual samples in terms of lost time, travel, etc. This is a component of search costs. Second, the costs of resolving disputes over misshipments are reduced. Third, the homogeneity resulting from grading limits the advantage of advertising which therefore reduces its incentive and ultimately its cost. Finally, the industry as a whole increases its efficiency by permitting suppliers previously operating on a local basis to market their product on a national or international basis.

Pricing efficiency may be defined as the capacity of the marketing chain to effect change and initiate a reallocation of resources in order to maintain a consistency between what is demanded by consumers and what is produced.[5] The pricing

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[3] J.H. McCoy, Livestock and Meat Marketing (Westport,Conn.:Avi Pub.Co.,1970)10.

[4] Ibid., 10.

mechanism serves as a communication system between producers and consumers and its efficiency is simply a reflection of how well the system works. A wheat grading system may increase pricing efficiency 1)through the standardization of terminology used throughout the marketing chain which permits the association of specific attributes of quality with particular grades, 2)by increasing the knowledge about the product which is ultimately reflected by price, 3)by accurately transmitting the preferences of the consumers back to the producers, 4)by facilitating the collection of market information including prices, and 5)by providing a medium through which market participants are assisted in making decisions concerning grades and prices.[6]

Advocates for a revision of the Canadian wheat grading system contend that the present system does not encourage efficient pricing of wheat.[7] The basis for this position is the belief that processing quality characteristics that are important to end-users are not clearly associated with particular grades (e.g. protein content).[8] That is, there is not a significant difference between grades in terms of some

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[5] W.Purcell, Agricultural Marketing: Systems,Coordination, Cash and Futures Prices (Reston,Virginia:Reston Publishing Co. Inc.,1979),9.

[6] Williams and Stout, Economics of the Livestock-Meat Industry, 486.

[7] J.Mants,E.Arnt,C. Maness,R. Roehle and A. Wilson, Wheat Grades for Canada-Maintaining Excellence, Canada Grain Council, (1985), 44.

[8] Ibid., 45.

criteria that are important to end-users. The effect of this factor may be magnified if the preferences of users are not transmitted back to producers. This may ultimately lead to an improper allocation of resources by producers.

It has been suggested that a second cause for the improper allocation of resources by producers relates to the refusal by the C.G.C. to license high yielding different quality (HYDQ) varieties of wheat.[9] Although they are generally of an inferior quality to spring wheat, HYDQ wheats are attractive to producers because they traditionally produce higher yields than spring wheats. However, the C.G.C. has refused to license HYDQ varieties (with the exception of HY320) on the basis that they are visually indistinguishable from spring wheat which could undermine the high quality standards of the wheat grading system. The reluctance on the part of the C.G.C. to license HYDQ wheats may be interpreted as an addmission that the present grading standards may fail to segregate wheat to its processing quality characteristics. That is, the C.G.C. apparently realizes that HYDQ wheats may be graded as No. 1 C.W.R.S. despite having significantly different processing quality characteristics. To avoid HYDQ wheats from being confused with No. 1 C.W.R.S. the C.G.C. has simply refused to license the majority of the HYDQ wheats despite there being a legitimate demand for their characteristics. This topic is certainly deserving of

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[9] C.A.Carter, R.M.A. Loyns, and Z.F. Ahmadi-Esfahani,"Varietal Licensing Standards and Canadian Wheat Exports." Cdn. J. of Agric. Economics 34 (1986):361-377.

further research. However, a void of data pertaining to HYDQ wheats has forced the exemption of these wheats from this study.

Unfortunately there is no published quantitative study that addresses the question whether there exist significant differences in processing quality characteristics between the grades of CWRS wheat. This study represents an attempt to fill some of the void in research on this question for the CWRS class of wheat.

1.3 OBJECTIVES

The primary objective of this study is to determine whether there is a significant difference in processing quality characteristics between grades of Nos.1,2 and 3 C.W.R.S. Achieving this objective will either support or refute the hypothesis that there is not a close relationship between grade and processing quality characteristics. If a close relationship is not not found, it will suggest that pricing efficiencies likely exist which in turn would imply that the grading system is less than ideal. The justification for the undertaking of this study is that this kind of evidence can be used to identify weaknesses in the existing grading system and should identify areas for improvement.

Underlying the primary objective are a number of secondary objectives. First, this study will review related economic literature in an attempt to determine the economic relevance of significantly different processing quality characteristics between grades. Second, this study will review research specifically concerned with the relationship between the grading standards and the processing characteristics with which they are expected to be correlated. Finally, given the empirical results generated by the investigation of these objectives, the study will conclude with a set of recommendations which are consistent with removing deficiencies in the existing grading system as a means of improving it.

Chapter II

LITERATURE REVIEW

2.1 COST VS. OPERATIONAL EFFICIENCY

The preceding chapter identified the potential economic gains resulting from grading wheat (increased operational and pricing efficiency) but ignored the opposite side of the ledger, the cost associated with implementing the grading system. The cost is important because for a grading system to be of any benefit to its users, its gains must exceed its cost. However, determining the real cost for the case of the Canadian wheat grading system would not directly contribute towards the objectives of this study. The following section reviews the cost of grading systems in relative terms as it relates to the economic gains derived from the system.

In general, the per unit cost of grading is small and usually less than the cost savings derived from the increased operational efficiency (e.g. reduced search costs, reduced disagreements over mis-shipments, reduced advertising costs) gained through grading.[10] Given that the sum of the direct and indirect costs attributed to grading are less than the savings from increased operational efficiency, it

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[10] Williams and Stout, Economics of the Livestock-Meat Industry, 480.

is usually assumed that grading results in a net reduction of marketing costs.[11] Through the following analysis, then, it will be assumed that the savings as a result of increased operational efficiency are greater than the cost of the grading system, resulting in a net decrease in marketing costs.

A decrease in marketing costs will ultimately affect the derived supply curve facing the consumer and the derived demand curve facing the producer. Given that the derived supply function is the sum of the marginal costs of production and marketing firms (Sc = Mcf + Mcm), a net decrease in the sum of the marginal cost of marketing should serve to decrease the supply function (shift it to the right). Given that the derived demand is the difference between the aggregate consumer demand and the sum of the marginal cost of marketing (Df =Dc - ΣMcm), a reduction in marketing costs will serve to shift the derived demand curve upwards to the right.

The effects of a reduction in marketing costs on the derived supply and demand curves are illustrated in a model taken from Williams and Stout[12] and illustrated in Fig.1. The following analysis makes several assumptions including; 1) all gains or losses resulting from grading are passed on to producers, consumers or both, 2) demand and supply func-

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[11] Ibid., 481.

[12] Ibid., 482.

tions are linear, 3) unit marketing costs do not vary with volume but are constant throughout, and 4) a change in consumer surplus is a valid measure of consumer welfare.

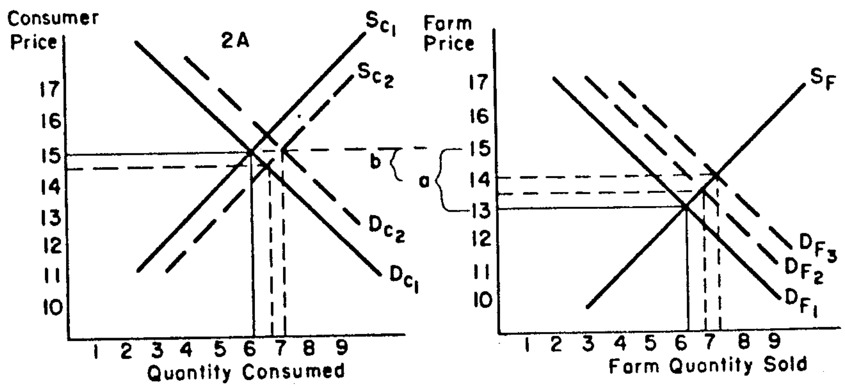

Fig. 1 Cost vs. Operational Efficiency

Given a decrease in marketing costs, the derived supply curve shifts to the right from Sc_1 to Sc_2 (Fig.1) and the quantity produced at any given price is increased. Likewise, as the derived demand curve shifts to the right, the quantity demanded at any given price increases. Quantity produced and consumed increases; producer prices increase while consumer prices decrease; producers and consumers share equally in the savings derived from the decrease in marketing costs.[13]

The distribution of the gains, however, depends on the relative elasticities of the derived supply and demand curves. A more inelastic supply curve would result in smaller quantities sold and consumed.[14] Most of the savings from

[13] Ibid., 483.

the reduced marketing costs would then accrue to the producers.

The above analysis acknowledges that there is a cost associated with grading but assumes that the cost is more than offset by an increase in operational efficiencies. Although the preceding discussion is fundamental for a complete review of the economics of grading systems, it did not discuss the economics of grading systems in terms of pricing efficiency. The following section focuses on price efficiency as it relates to the present wheat grading system in Canada.

2.2 ECONOMICS OF PRICE EFFICIENCY

In order to assess the present grading system as it relates to pricing efficiency, it is necessary to identify a model against which the existing system can be compared. Moreover, one has to demonstrate that a significant difference in processing quality characteristics between grades is a necessary condition for an optimal grading system and then review the related technical studies. The first part of the literature review, then, reviews a series of economic models drawn from Williams and Stout[15] and adapted to the Canadian grain market. The second part of this chapter reviews the related technical studies.

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[14] Ibid., 483.

[15] Ibid., 473-478.

The models with which the Canadian wheat grading system will be compared are the indifference curve models presented by Williams and Stout. Three different models will be examined.

The first model assumes that a grading system does not exist so that the millers are unable to determine the levels of test weight and vitreousness in a given sample, two grading factors understood to be important to the way millers evaluate wheat. Without any specific information on these grading factors, millers would be inclined to pay the same price for the two samples(i.e. high test weight, low level of vitreous kernels vs. low test weight, high level of vitreous kernels) which would yield very different results upon milling. This relationship is represented in Fig.2 by the slope of the budget line A_1A_1' which is equal to one.

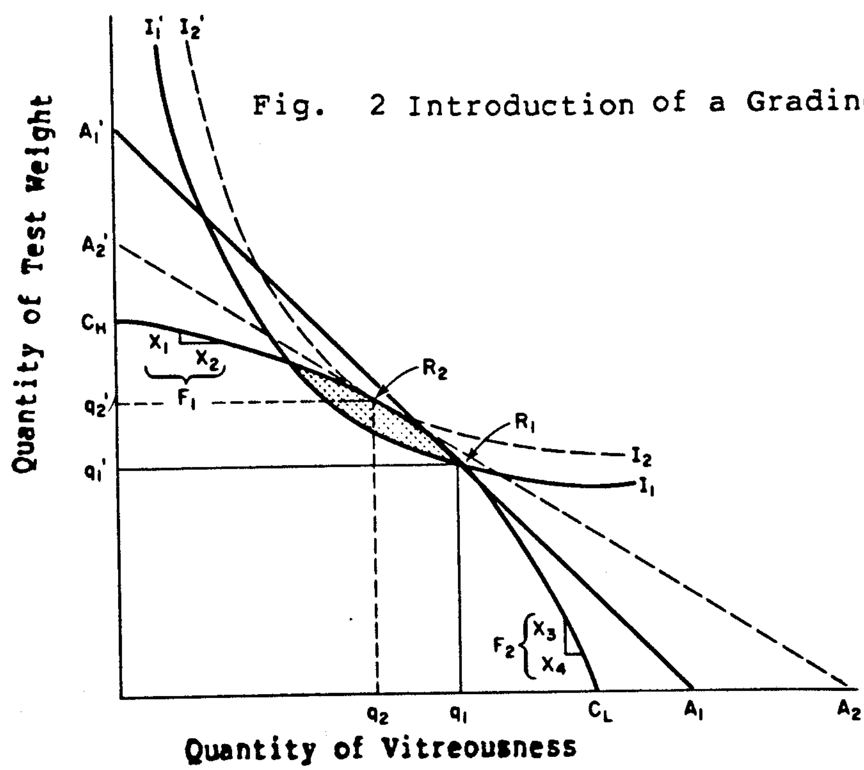

Fig. 2 Introduction of a Grading System

A second assumption regarding A_1A_1' fixes expenditures by millers which they are unwilling to increase or decrease. Millers can, however, unknowingly purchase samples containing any combination of the grading standards represented by A_1A_1'. This assumption is key to the analysis of the first model. Assuming fixed expenditures by millers is equivalent to assuming that the introduction of a grading system does not change the marketing margin facing the miller. Support for this assumption is drawn from the case where the added cost of the grading system is exactly offset by the gains resulting from increased operational efficiency, a plausible scenario.[16] This assumption effectively eliminates the effects of the costs of the grading system and the change in operational efficiency and isolates the effects that the grading system has on price efficiency.

Wheat producers are the second group of participants included in the model. Assume that producers' expenditures are also fixed. Given this assumption ChCl, the production possibility frontier(PPF), represents the alternate combinations of test weight and vitreousness that may be derived from a given expenditure i.e. it represents the transformation of test weight into vitreousness or vice versa. The concave position of the PPF relative to the origin implies an increasing marginal rate of transformation(MRT).

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[16] Ibid., 481.

For maximum economic efficiency, the processing(i.e. derived demand) and production sectors must be in equilibrium; this occurs where the slope of the budget line of the miller (A_1A_1') is equal to the slope of the PPF of the producer (ChCl). Since the slope of A_1A_1' is equal to one and the slope of ChCl is equal to the rate of transformation from test weight into vitreousness, the optimizing condition is represented by the following equation,

$$\frac{\text{test weight price}}{\text{vitreousness price}} = \frac{\text{marginal cost of vitreousness}}{\text{marginal cost of test weight}}$$

This condition is represented by the point R_1 in Fig.2, the point of tangency between A_1A_1' and ChCl.

Now let us assume that the preferences of all millers can be aggregated and represented in this model by indifference curves. In the context of this model indifference curves represent those combinations of test weight and vitreousness among which millers are indifferent. Further, assume that indifference curves are convex to the origin, never cross one another and that the level of utility increases as one moves away from the origin. To maximize utility or satisfaction, millers must choose that combination of test weight and vitreousness corresponding to the point where the budget line A_1A_1' is just tangent to an indifference curve. Returning to equilibrium, quantities q_1q_1' do not represent those quantities of test weight and vitreousness that maximize utility. A reduction of vitreousness to q_2 and an increase of test weight to q_2' would allow millers to attain a higher level of utility, I_2I_2'. However, in the absence of a grading system millers are unable to display their preferences and production remains at q_1q_1' and utility is limited to a level of I_1I_1'. This indicates the basic problem of failure to maximize utility from a given resource utilization because of a lack of a grading system.

Now assume that a grading system is introduced that will segregate samples on the basis of test weight and vitreousness. Millers will attempt to increase their level of utility to I_2I_2' by increasing their purchases of test weight and decreasing their purchases of vitreousness. The relative change in their purchases of the two grading factors will lead to a change in the relative prices of the grading factors. The increased purchases of test weight will lead to an increase in its price relative to the price of vitreousness. This is illustrated by a decrease in the slope of the budget line to A_2A_2'. Production is changed to q_2q_2' to regain equilibrium in the production-consumption sectors and the optimum condition is found at R_2.

At this point it may be argued that if the cost of the grading system is borne by the millers, the added cost will effectively shift the budget line inwards towards the origin. However, this argument is negated by the assumption that the expenditures by the millers are fixed. Support for this assumption is drawn from studies that have indicated that marketing margins may remain unchanged as a result of increased operational efficiency offseting the added cost of the grading system.[17] Any change in the position of the budget line, therefore, is a result of the relative change in the price of test weight and vitreousness.

By conventional economic analysis, this framework illustrates how a grading system improves pricing efficiency. In summary, increased pricing efficiency as denoted by the achievement of a higher level of utility was achieved by 1)enabling millers to demonstrate their preferences through price differentials, 2)reflecting the millers' preferences to the producers via the price differentials, and 3) allowing producers to allocate their resources in accordance with the millers' preferences. The social gains derived from the introduction of the grading system, measured in terms of utility, are identified as the cross-hatched area in Fig. 2.

With resect to the movement along the production possibility curve from R_1 to R_2, it is not indicative of an increase in operational efficiency because the level of technology represented by R_2 was available to producers before the grading system was introduced. Moving from R_1 to R_2 obviously indicates a change in technical efficiency but it cannot be concluded that it is a result of increased operational efficiency.

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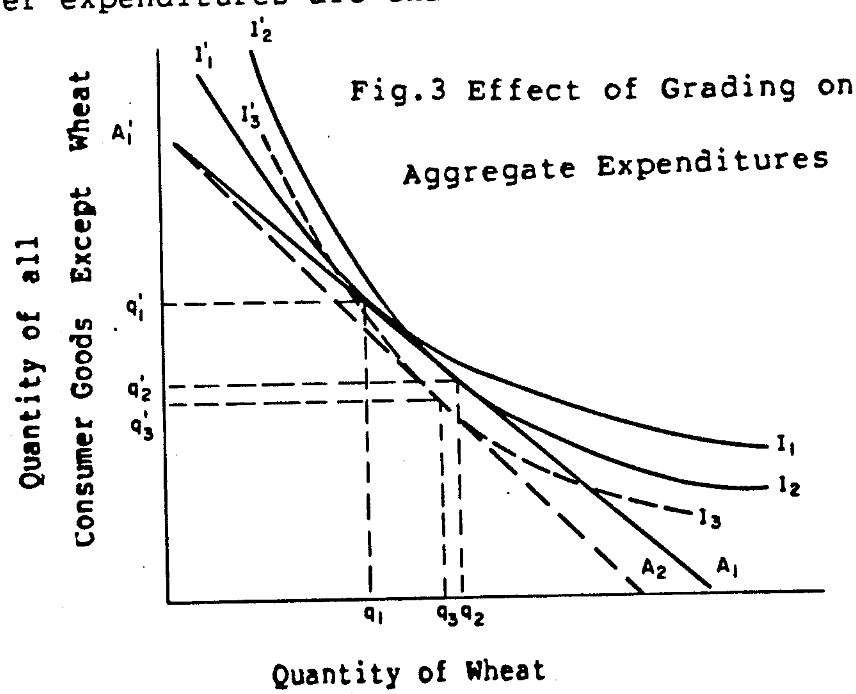
[17] Ibid., 481.

The applicability of the above model is limited by the assumption that all millers' preferences are the same. In a second model (not illustrated) Williams and Stout[18] address this limitation by extending the model to include two groups of millers each having distinctly different preferences and levels of expenditures. In this case each group would attempt to purchase the grading standards that they most preferred. In doing so, the prices of the preferred standards would increase and the prices of the less desirable standards would decrease. Finally, the net change in prices would depend on the relative strength of the two groups, changes in preferences and changes in real income.

In the third model, the possible effects of grading on aggregate expenditures on wheat by millers relative to all other expenditures are examined.



[18] Ibid., 476.

In Fig.3 A_1A_1' represents the budget line of the millers and I_1I_1' the aggregate indifference curve prior to the introduction of a grading system. Initially I_1I_1' is tangent to A_1A_1' and quantities q'_1q_1' are purchased. With the introduction of a grading system the graded wheat becomes more expensive relative to all other goods. This causes the budget line to rotate inwards to A_2A_1'. However, the introduction of the grading system also provides the millers with a greater assurance of the quality of wheat being purchased, a point previously demonstrated by the first model(Fig.2). The greater level of assurance on the part of the millers is illustrated by the indifference curves being rotated to I_3I_3'. The shift of the indifference curves indicates that for any given level of wheat, millers will demand a larger quantity of all other goods in exchange for one unit of wheat. At the new equilibrium point, aggregate expenditures on wheat are increased at the expense of all other goods.

The foregoing analysis demonstrates some very basic but crucial economic concepts concerning the gains accruing from grading systems. First, if a grading system is implemented and no gains are derived from it, the added cost of the grading system will lead to a loss of utility. This is illustrated in Fig.3 by an inward rotation of the budget line without a corresponding change in the orientation of the indifference curves.

The foregoing analysis demonstrates a second point with respect to the cost vs. the utility gained from a grading system. In order to avoid a loss of utility, the sum of the change in the operational and pricing efficiencies must at least equal the inherent cost of implementing the grading system. Figure 3 addresses only the effect that the increased pricing efficiency has on the level of utility. Therefore, the exclusion of operational efficiency from this model makes it impossible to determine from Fig.3 whether the introduction of a grading system will ultimately lead to an increased level of utility.

Figure 3 is useful, however, in demonstrating that the increased pricing efficiency can lead to a re-orientation of the indifference curves which is necessary to avoid a loss of utility. Assuming that the increased pricing efficiency is a result of increased assurance on the part of the buyer, indicated by an increased MRS(marginal rate of substitution), the level of pricing efficiency is directly related to the level of utility ultimately attained. Where a grading system does not provide any increase in assurance to the buyer, the original utility curves in Fig.3 remain unchanged and it is not clear that an increase in utility is attained.

To ensure that there is an increase in pricing efficiency and a corresponding increase in utility, a minimum and necessary requirement of a grading system is a significant difference between at least some of the grades[19] in terms of processing quality characteristics. For an optimum grading system this condition becomes more stringent. The grading standards should maximize the differences in relevant characteristics between grades and minimize overlapping.[20]

The preceding models initially depict a scenario in which grading systems do not exist and subsequently introduce grading systems to examine its effects. Although the end results of introducing a grading system are made clear (increased operational and pricing efficiency) the above models do not explain the forces that actually initiate a grading system to evolve. A model developed by Farris[21] provides an possible explanation for the evolution of the Canadian wheat grading system.

Farris suggests that product differentiation may serve as a precursor for the application of grading standards to a good. The motive for product differentiation by individual firms is increased profits through non-price competition. If a firm is financially successful at differentiating a product through the variation of a quality attribute, that variation may be adopted by the industry thus eliminating any advantage the originating firm may have had. Where product

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[19] Ibid., 487.

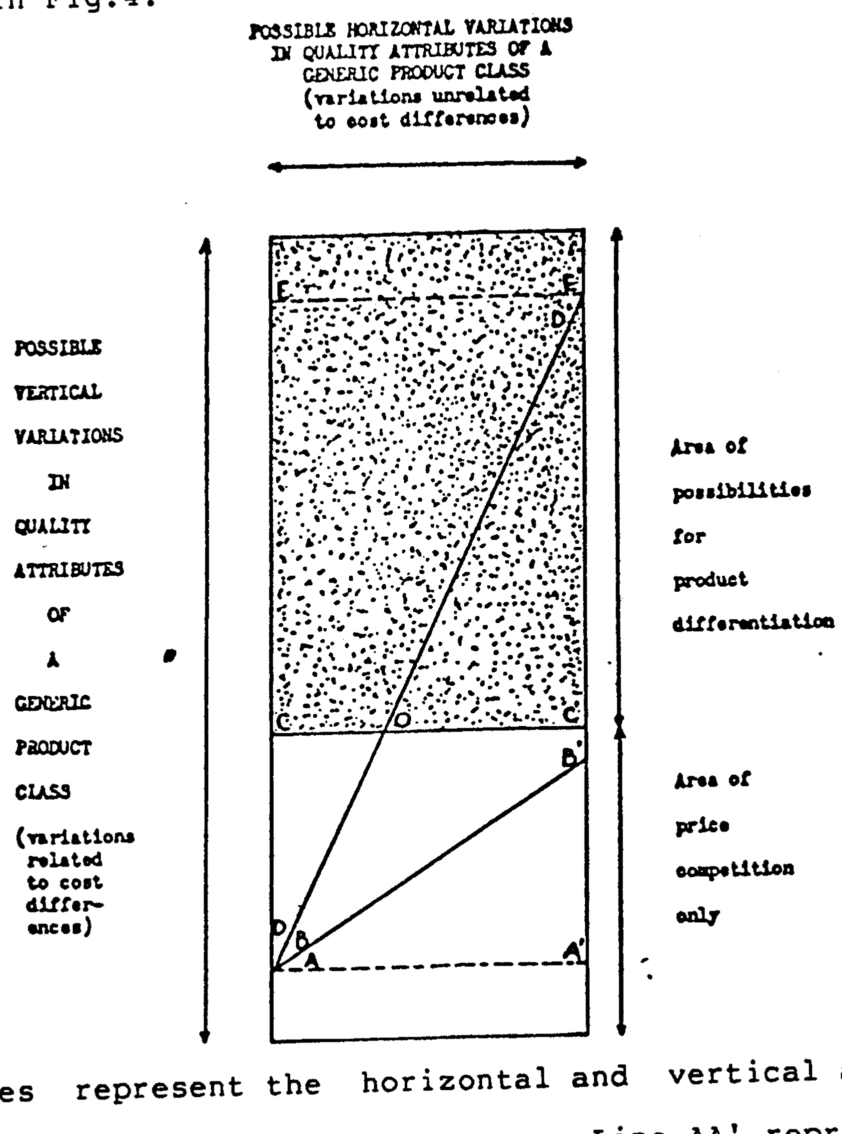
[20] Ibid., 487.

[21] Paul L. Farris, "Uniform Grades and Standards, Product Differentiation and Product Development." Journal of Farm Economics. 42 (1960) :854-863.

differentiation leads to the adoption of a product attribute variation throughout the industry in the form of a grading standard, there returns the incentive for a firm to again differentiate its product by further product attribute variation.

The potential evolution of grading standards is illustrated in Fig.4.

Figure 4



The axes represent the horizontal and vertical attributes that a generic product may possess. Line AA' represents the lowest level of attributes that are acceptable. Products having attributes below AA' are not suitable for any commercial use.

Line BB' represents the minimum acceptable standards for health and safety. The increasing slope of BB' suggests that there are varying degrees of acceptable standards for different uses.

Line CC' indicates the current maximum standardization of processing characteristics for the product. Below CC' products may possess any combination of horizontal and vertical processing characteristics but because end-users are sufficiently knowledgeable regarding the processing characteristics, product differentiation is impossible and competition between firms is strictly in the form of price.

The shaded area above CC' represents an area of product quality attributes that remains to be explored by the industry. Product differentiation provides a means by which firms may attempt to extract the possible gains within this area. As a result there is a continuing upward pressure on line CC' as firms realize the potential gains through product differentiation. Besides advances in grading techniques, improvements in marketing, production and distribution will contribute to the upward pressure on line CC'. Eventually the pressure will be transformed into 1) an increase in the average quality levels of products, 2) more accessible quality attributes that were previously not attainable and 3) a search for new differentiating factors.

Line DD' represents the practical limits of standardization. The upward sloping orientation of line DD' indicates that there exist different requirements by end-users in terms of quality attributes. The cost of the product increases moving from left to right as a result of increasing quality demands.

Finally line EE' represents the upper boundary of product variation. The area above line EE' represents product variation that is infeasible because its cost would not be recovered by the price end-users would be willing to pay.

With resect to the Canadian wheat grading system, the horizontal axis of Fig.4 represents the horizontal presentation of protein content. The vertical axis represents the grading standards. Line CC' represents the current state of the grading system.

It is the rectangular area CC'EE' that is of relevance to this study. The indifference curve models served to conclude that a significant difference in processing quality characteristics is a necessary requirement for pricing efficiency to occur. If it can be shown that there is no difference between grades in terms of processing quality characteristics, area CC'EE' of Fig.4 is potentially available for further research. First, a review of the related technical studies that have investigated the differences in processing quality characteristics between grades is necessary. The following section identifies the characteristics of wheat that are of importance to its end-users and reviews the related technical studies that have investigated the differences of these characteristics between grades.

2.3 REVIEW OF RELATED TECHNICAL STUDIES

The review of the economic models (above) serves to support the concept that a significant difference in processing quality characteristics of different grades is a necessary condition for an optimal wheat grading system. The models described also serve to justify the review of the related technical studies. However, the paucity of technical research publications on differences in processing quality characteristics between grades necessitates that a review of related technical studies follow an indirect approach. In this context, it is presumed that an insignificant difference between grades in terms of processing quality characteristics exists as a result of an insignificant relationship between the grading standards and the processing quality characteristics. The relationship between the grading standards and processing quality characteristics will therefore be reviewed as a basis of potential inferences on relationships between the differences in processing quality characteristics and grades. For example, if research results indicate an insignificant relationship between grade standards and processing characteristics, then it can also be inferred that there exists an insignificant relationship between grades in terms of the processing characteristics since the grades are defined by the grading standards.

The approach will be clarified by a specific example. Test weight has been implemented as a grading standard because it is perceived to be related to flour yield, an important processing characteristic. If, however, research results indicate an insignificant relationship between test weight and flour yield, then it may be inferred that flour yield is not significantly different between grades since the grades are defined by test weight. Research on other grading standards will be reviewed similarly. Before embarking on the review, it is necessary to explain what is meant by the phrase "processing quality characteristics" in the context of this dissertation.

2.3.1 Processing Characteristics Related to End-Use Quality

Wheat is the primary ingredient for many foods including breads, biscuits,pastries, cakes,pasta,noodles,porridge and bulgur. Each product requires a flour with processing characteristics that are specific to that product. Consequently the criteria used to assess flour quality by one miller may not be the same as that used by another miller who may be milling flour for a different end-product. This precludes any one processing quality characteristic of wheat from being an absolute measure of its quality; each end-use requires a unique set of characteristics.

In general, the evaluation of wheat for the purpose of milling into flour is based on tests for moisture content, test weight,1000-kernel weight, protein content, Falling Number value, sedimentation value and flour yield derived from experimental milling.[22] Each of these tests possesses a desired range of values.Test values beyond the desired range may reflect poorly on the sample but are usually not considered in isolation from the other test values. Likewise, favorable results from a single test generally do not compensate for deficiencies in other test results which reflect poorly on the sample.[23]

Information on potential bread yield and quality is sought by bakers through the use of tests on experimentally milled flour. Ash content,color,starch damage,protein content,gassing power, amylograph viscosity,water absorption by the farinograph test, rheological properties measured by the extensograph and/or alveograph, and dough development time by farinograph are criteria used by bakers to evaluate samples of flour. Again, there exists a range of acceptable results for each test. However the limits of the acceptable range is determined in a subjective manner and can vary significantly between bakers.[24]

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[22] G.N. Irvine, "Wheat and Its Quality", Proceedings of the Canadian Centennial Wheat Symposium. Modern Press, Saskatoon, 1967, 119.

[23] Ibid., 119.

[24] Ibid., 120.

Ideally, appropriate processing criteria should be used as the grading standards to segregate wheat. However, as noted previously, test weight, degree of soundness, maximum percentage of vitreous kernels, percentage of foreign material and percentage of wheats of contrasting classes are employed as grading standards in favor of the processing quality characteristics indicated above.

The reason for not using the processing quality characteristics is clear. Prerequisites for grading standards are that they be quickly and easily administered at all levels of the handling and marketing chain at a cost that does not exceed the gains derived from it. Many of the above processing quality characteristics presently do not meet these prerequisites. In general, the processing quality criteria are determined by the laborious efforts of technicians at relatively high cost. Furthermore, they require more time than is normally available at each grading point in the handling system.

As a result, the present grading standards have been employed as an alternative to the processing quality characteristics. In such cases where the processing quality characteristics cannot be determined directly as a grading standard, there must exist a significant relationship between the processing characteristics important to end-use and the grading standards which are used as proxies. The following subsections discuss each grading standard individually, its theoretical relationship to specific processing quality characteristics and a review of research pertaining to those relationships.

2.3.2 Test Weight

Test weight(previously in pounds per bushel, now in kilograms per hectolitre) is one of the most widely-used criteria of grain quality for grading purposes. It may be defined as the weight of grain per unit volume. The Canadian Grain Commission sets standards in terms of kilograms per hectolitre although the trade in Canada and the U.S. routinely refers to pounds per bushel. Its inclusion as a grading factor is based on its perceived direct relationship to flour yield.[25] Theoretically, low test weights are indicative of the presence of shriveled kernels which,when milled, produce comparatively lower yields of flour than do plump kernels. The lower flour yields from shriveled kernels result from a lower ratio of endosperm to bran.

Study of the relationship between test weight and flour yield(an accepted index of milling quality) began some sixty years ago when Mangels and Sanderson studied 1606 samples of Hard Red Spring (HRS) wheat from the 1916 and 1919-1924 crop years. Arriving at correlation coefficients between 0.72 and 0.82, they concluded that the use of test weight per bushel

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[25] Y. Pomeranz, Quality Control for the Food Industry, ed. Amihud Kramer, Bernard A. Twigg (Westport Connecticut: The Avi Publishing Co. Inc.),271.

as a grading factor was justified on the basis of its relationship to flour yield.[26]

Subsequent studies have both supported and contradicted this relationship. Shuey examined 287 lots of wheat and found a correlation coefficient (0.744) comparable to that of Mangels and Sanderson. However Shuey concluded that a grain sizing technique which increased the correlation coefficient to 0.957, was a better indicator of flour yield than was test weight.[27]

Using a slightly different approach, Baker et al concluded that the correlation coefficient between test weight and flour yield was specific to the class of wheat;for HRS wheat it was 0.365.[28] More recently Watson et al al[29] found a correlation coefficient of 0.48 which is closer to that of Baker et al than that of Shuey or Mangels and Sanderson. Finally, the results of a study by Hook[30] cast further doubt on the relationship between bushel weight and flour yield.

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[26] G.E.Mangels and T.Sanderson,"Correlation of Test Weight Per Bushel of Hard Spring Wheat With Flour Yield and Other Quality Factors." Cereal Chem 2 (1925): 365-369.

[27] W.C.Shuey,"A Wheat Sizing Technique for Predicting Flour Milling Yield." Cereal Sci. Today 5 (1960): 71-72.

[28] R.J.Baker,K.H.Tipples and A.B.Campbell,"Heritablities of and Correlations among Quality Traits in Wheat." Can. J. Pl.Sci 51 (1971): 441-448.

[29] C.A.Watson,L.D.Sibbitt and O.J.Banasik, "Relation of Grading and Wheat Quality Factors to End-Use Quality Characteristics for Hard Red Spring Wheat." Bakers Dig 51(1) (1977): 38.

[30] S.C.Hook,"Specific Weight and Wheat Quality." J. Sci. Food Aric 35 (1984): 1136-1141.

This study led to the conclusion that no justification could be found for using test weight as a quality characteristic. Based on these published studies using commercial lots of wheat, it is concluded that there is unlikely to be a significant correlation between test weight and flour yield. This implies that a grading system which is based upon the existence of such a correlation will be suboptimal, particularly since correlation is related to an indirect measure (test weight) of the real quality factor (flour yield).

2.3.3 Variety

Schedule I of the Canada Grain Act which lists the grade determining factors for the CWRS class of wheat includes "variety" as a standard of quality by stipulating that in order to grade No. 1,2 or 3, the grain must be any variety that had been previously officially declared as being equal in quality to Neepawa. This declaration occurs at the time the variety is registered by the Food Production and Inspection Branch of Agriculture Canada for commercial production. In 1988 the list of registered varieties in the CWRS comprised 21 varieties.[31] Many of these varieties are grown on small acreages in localized areas. In 1988, three closely related (genetically) varieties, Columbus, Katepwa and Neepawa, covered 88.5% of the Prairie bread wheat acreage. The

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[31] P.K.W. Ng, M.G. Scanlon and W. Bushuk. "A Catalog of Biochemical Fingerprints of Registered Canadian Wheat Cultivars by Electrophoresis and High Performance Liquid Chromatography 1988." p.2, Food Science Department, University of Manitoba.

fourth ranked variety, Park, covered only 2.8% of the acreage.[32]

Varieties included in the C.W.R.S. class have their own unique set of agronomic characteristics such as resistance to diseases and insects and inherent yield but all are of similar milling and baking quality. The registration system for CWRS wheat effectively curbs the introduction of other varieties. The grading system takes into account the varietal standard by specifying the same standard, Neepawa, which must be met by all other varieties if the grain is to qualify for grades Nos.1,2 and 3 CWRS.

The inclusion of variety as a grading standard ensures that the inherited component of processing characteristics is maintained at approximately the same level for all varieties within a grade class. This is one of the key factors that contribute to the uniformity of quality of the grain in a single grade. Of the other wheat producing countries, only Australia has a varietal requirement in their standards for the Prime Hard and Hard grades of Australian Standard White class of wheat.[33] The varietal standard in the Australian wheat grading system is administered differently than in Canada(see above). Assignment of a grade to

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[32] Prairie Pools Inc. Prairie Grain Variety Survey. 1988. A report prepared by the Prairie Pools, Regina, SK., Table 1.

[33] W. Bushuk." Wheat Class Identification and Segregation in Canada and Australia." in Wheat Production in Canada, A.E. Slinbard and D.B. Fowler,eds. University of Saskatchewan, Saskatoon,Sk., 603-613.

the farmer's delivery is based on a signed declaration of the variety name.

The varietal standard differs from the other grading factors in that it does not segregate Nos.1 and 2 CWRS into graduated levels. Instead, a single variety is applied as the standard for both grades. Since both grades are subjected to the same varietal restriction, it may be inferred that variety does not act to distinguish processing quality characteristics between grades. Rather, variety is more concerned with the exclusion of different varieties, an objective of the grading system that is not at issue in this study. Therefore, since technical research has not pursued the relevance of variety in terms of differences in processing quality characteristics between grades, it will not be pursued further in the present study.

Given that variety does not distinguish processing quality characteristics between grades, the basis for its inclusion focuses solely on the exclusion of varieties having processing quality characteristics different from Neepawa. Having previously stated that wheat is the primary ingredient of a large number of products, the inclusion of variety as a grading standard could potentially exclude varieties which do not possess superior breadmaking qualities but which nonetheless may be demanded by end-users. In such a case variety may act as a constraint by inhibiting efficient pricing since an allocation of resources between what is demanded and what is produced is not guided by market forces.

2.3.4 Vitreousness

Vitreousness refers to the degree of glassy or transparent appearance of the wheat kernel. Non-vitreous kernels appear starchy or opaque. In Canadian wheat grading, it is expressed in terms of percentage of "hard vitreousness kernels". By regulatory definition of the C.G.C., this grading factor also includes broken or otherwise physically damaged kernels. The inclusion of vitreousness as a grading factor relates to its perceived correlation to hardness.[34] Kernel hardness in turn is theoretically affected by protein and moisture contents.[35] Extremely hard milling characteristics may lead to a decrease in flour quantity whereas soft wheats yield fine flour desirable for cakes and pastries but not for breads.

The reasons as to why vitreousness is a grade standard is not clear. The relationship between vitreousness and protein content has been the subject of numerous studies that date back to Confederation. Sharp[36] provided a brief review of the earliest studies that supported a direct relationship between vitreousness and protein content. In 1925 Mangels

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[34] Y. Pomeranz, Quality Control for the Food Industry, 271.

[35] Ibid., 271.

[36] P.F. Sharp, "Wheat and Flour Studies IX. Density of Wheat as Influenced by Freezing, Stage of Development and Moisture Content." Cereal Chem 3 (1927): 14.

and Sanderson provided results that contradicted this relationship. Based on a study of the 1922-24 North Dakota Hard Spring Wheat(HSW) crop, they concluded that the percentage of dark hard vitreous kernels could not be considered a reliable index of protein content.[37] Subsequent studies focused on several factors thought to influence vitreousness including farming practices, the environment and heredity. While these studies are of importance, they did not clarify the relationship between vitreousness and protein content.

It was not until the mid 1970's that a resurgence in research on this subject began. The 1973 and 1975 U.S. winter wheat crops were characterized by the lowest average protein content of the previous twenty-five year period and an increase in the presence of yellow berry(YB) or non-vitreous kernels. The influx of yellow berry hard winter wheat into the marketing system was met with uncertainty and resistance by the importers such that discounted offers were rejected. The confusion within the marketplace and the practice of discounting by exporters initiated several studies concerning vitreousness and milling and baking qualities.

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[37] G.E.Mangels and T.Sanderson,"Correlation of Test Weight Per Bushel of Hard Spring Wheat with Flour Yield and Other Quality Factors." Cereal Chem 2 (1925): 365-369.

[38] D.P.Phillips and F.F.Niernberger,"Milling and Baking Qualities of Yellow Berry and Dark,Hard and Vitreous Wheats." Bakers Dig 50(1) (1976): 42.

One relevant study by Phillips and Niernberger[38] used 1560 samples of HRW wheat from the 1972-75 crop years to clarify the relevance of vitreousness as a grading factor. The results supported two important hypotheses. First, at the same protein level there were no significant differences in the milling and baking qualities of samples of different levels of vitreousness. Second, wheat protein was found to be a better indicator of flour quality than the percentage of dark hard vitreous (DHV) kernels from which it was milled. Based on these findings, it was concluded that sub-classes determined by vitreousness were redundant and better measures of quality(e.g.protein content) were available.[39]

The events of the 1970's initiated a second study by Pomeranz et al. Laboratory milling and baking tests were performed on 14 commercial and 6 varietal HRW wheat samples varying in protein content and vitreousness. Protein was again found to be a satisfactory index of breadmaking quality while vitreousness was found to be unsatisfactory.[40]

By May 1977 the Grain Division, Agricultural Marketing Services, U.S.D.A. had eliminated the grading subclasses of HRW wheat based on the poor correlation between vitreousness and bread baking quality(Watson et al,1977). At the same time the Grain Division proposed that protein be included as

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[39] Ibid., 42.

[40] Y.Pomeranz,M.D.Shogren,L.C.Bolte and K.F.Finney, "Functional Properties of Dark Hard and Hard Red Winter Wheat." <u>Bakers Dig</u> 50(1) (1976): 42.

a grading factor because of its high correlation with baking quality. However the proposed changes involved only HRW wheat, excluding HRS wheat because of a lack of research data pertaining to this class of wheat.

Subsequently Watson et al[41] undertook a study to partially evaluate the grading system for HRS wheat. Samples of HRW wheat from the 1971-75 North Dakota crops were analyzed as individual and composite samples. For this class of wheat, Watson et al concluded that vitreousness could not be used to predict protein content.[42] Their conclusion was based on variations in the magnitude and the sign of the correlation coefficient. Furthermore, it is well known that vitreousness can be readily destroyed by as little as one cycle of wetting and drying whereas protein would be unaffected. Nevertheless, kernel vitreousness remains a grading factor for U.S. HRS and durum wheat classes.

There have been no Canadian studies of the significance of vitreousness as a grading factor for the Canada Western Red Spring class of wheat. While there seems to be no technical reason for retaining it, the market place recognizes that a wheat sample with a high percentage of hard vitreous kernels has an attractive appearance which gives a perception of superior quality. Accordingly, it will probably

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[41] C.A.Watson,L.D.Sibbitt and O.J.Banasik,"Relation of Grading and Wheat Quality Factors to End-Use Quality Characteristics for Hard Red Spring Wheat." <u>Bakers Dig</u> 51(1) (1977): 38.

[42] Ibid., 38.

remain a part of the Canadian wheat grading system well into the future.

2.3.5 Soundness

Soundness is the most subjective grading factor. It is mostly concerned with the measure of the degree of kernel maturity and damage. Kernel damage is a term covering many types of deformities caused by frost,heat,mold and other types of damage. Each type of damage affects the milling and baking qualities in a unique way(Hyslop p.5).

In 1930 Newton and Malloch[43] studied the effect of frost on wheat at various stages of maturity and concluded that frost reduced flour yield at all stages of maturity, the reduction being directly related to the stage of maturity and the degree of frost damage. As well, frost was found to have an adverse effect on the baking quality of immature samples but little effect on that of mature samples. Newton and Malloch concluded that in wheat, the reduction in grain yield caused by immaturity and frost was significant while the deterioration in quality was less than expected.

In 1937 Malloch et al examined samples from annual surveys of the 1930 to 1935 crops to determine the effect of frost on milling and baking quality. Again it was found that frost damage had the most pronounced effect on quality

[43] R.Newton and J.C.Malloch,"Variation in the Quality of Wheat Grown in Replicate Plots." Science Agron 10 (1930): 669-677.

when the kernels were immature. Malloch concluded that, with regard to frost damage and maturity, soundness was a fairly good index for milling quality but a poor indicator of baking quality.[44] It was concluded that the decrease in flour yield was due to the tough and fibrous nature of middlings of immature frosted kernels.

In 1985 Dexter et al studied the effect of frost damage on the milling and baking performance of Canadian hard red spring wheat. Cargo samples of Canada Feed wheat, obtained during a two month period in 1983, were used to determine the ability of the Canadian grain grading system to predict end-use quality of CWRS wheat by visual assessment of frost damage. It was concluded that as the degree of frost damage increased, flour yield decreased, flour ash increased and flour color deteriorated. Likewise baking quality deteriorated with increased frost damage which was traced to poor gluten quality.[45]

The second important contribution to the soundness factor is sprouted kernels. The percentage of sprouted kernels is included as a grading standard because it is a reasonably reliable indicator of an important starch-degrading enzyme called alpha-amylase. A small amount of alpha-amylase is

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[44] J.C.Malloch,W.F.Geddes,R.K.Larmour and A.G.McCalla,"The Quality and Grading on Frosted Wheat." Can.J.Res. 15 (1937): 567-592.

[45] J.E.Dexter,D.J.Martin,K.R.Preston, K.H.Tipples and A.W.MacGregor,"The Effect of Frost Damage on the Milling and Baking Quality of Red Spring Wheat." Cereal Chem 62(2) (1980): 75-80.

necessary for bread-dough fermentation. The optimum level of alpha-amylase activity may be exceeded due to the presence of sprouted kernels or it may be insufficient in which case malted wheat or barley flour may be added after milling.

Although it is common knowledge that the presence of sprouted grain results in a high level of alpha-amylase activity, research has also shown that excessive levels of the enzyme may be present in some samples of sound grain.[46] Even though visual sprouting may not be present, excessive levels of alpha-amylase may be present as a result of a wet harvesting. In cereal technology this condition is referred to as "incipient" sprouting. Thus, the percentage of sprouted grain cannot always be used as an accurate index of alpha-amylase activity.[47] In many cases, the alpha-amylase activity must be measured directly by appropriate analytical procedures.

The above review has indicated that the use of soundness as a grading standard is justified based on the relationship between frost damage and milling and baking quality. Moreover, the above review indicates that percentage of sprouted grain is not always a reliable indicator of alpha-amylase activity. Further research is needed on the development of

[46] Lawrence Zeleny Wheat: Chemistry and Technology, ed. Y. Pomeranz (St.Paul, Minn.: American Association of Cereal Chemists, 1964),33.

[47] Ibid., 33.

direct methods for measurement of alpha-amylase activity that would be compatible with a rapid grading system.

2.4 FOREIGN MATERIAL

Foreign material may be defined as material present in the sample other than the grain being graded. This may include chaff, straw,hulls, (grain of) other cereal grains,weed seeds and wheats of other classes admixed during harvest. Foreign material has been included as a grading factor for two reasons. First, it detracts from the total utility of a sample by reducing flour quantity. Processors usually remove foreign material which results in a loss of weight and a reduction in the yield of the end product. Secondly, foreign material that is inseparable may affect flour quality. This category includes grain of wheat of other classes which is not separable by the usual cleaning machines available in grain elevators and flour mills. The maximum allowable limit for the lowest milling grade is 10%.

The basis for utilizing foreign material as a grading factor may be justified intuitively. If the foreign material in a given sample is found to be separable, flour yield is decreased in direct proportion to the proportion of foreign material that is extracted. If the foreign material in a given sample is found to be both inseparable and deleterious to flour quality, the adverse influence of the foreign material may again be proportionate to the extent that it is present(e.g. impurities affecting flour color). If the foreign material is efficiently separated prior to milling, the intrinsic properties of the wheat will be fully recovered. Given the above relationships, it may be concluded that the inclusion of foreign material as a grading factor serves to indirectly produce significant differences in processing quality characteristics between grades. Therefore, the inclusion of foreign material as a grading factor will not be pursued.

2.5 CONCLUSION

The foregoing review of related literature has served two purposes. First, it has illustrated that a significant difference in processing quality characteristics between grades is a necessary condition for a grading system to promote pricing efficiency. This condition was demonstrated by the review of several economic models. Second, while the review of the technical studies failed to illustrate that there exists a significant difference in processing quality characteristics between grades, the review did establish sufficient concern to warrant further research. The following analysis attempts to answer those concerns.

Chapter III

APPROACH, DATA AND STATISTICAL METHOD

3.1 APPROACH

The approach taken by this study included 1)obtaining test results (by grade) on the processing quality characteristics described above and 2)performing the statistical analysis on the above test results and grouping together those results that proved not to be significantly different. Theoretically, if the processing quality characteristics are not related to grade the statistical test would group all test results together. In such a case the grading system would not enhance pricing efficiency as end-users would have little assurance of the quality of a wheat sample. If the processing characteristics are related to grade, then the statistical analysis should segregate the test results according to grade.

3.2 STATISTICAL METHOD

The analytical procedure involved the application of a statistical test to the data described below. The statistical test that was administered is referred to as a "Duncan's Test."[48] The Duncan's Test states that for the means of two

[48] D.B. Duncan. "Multiple Range and Multiple F Tests." Biometrics 3 (1955): 1-42

samples to be significantly different the shortest significant range must be less than the difference between the means. The shortest significant range is the product of the significant studentized ranges and the standard error. When the shortest significant range is less than the difference between the means, there does not exist a significant difference between the means.

The statistics necessary to compute the Ducan's Test include a) the means of the data being tested, b) the standard error of each mean (Sm), and c) the degrees of freedom on which the standard error is based. The degrees of freedom and the sample size are used to determine the significant studentized ranges which are drawn from a table entitled "Significant Studentized Ranges For a 5% Level New Multiple Range Test."[49] The significant studentized ranges are then multiplied by the standard error to produce the shortest significant range which is then compared to the difference between the means.

The validity of the Duncan's Test results rest on several assumptions regarding the data. First, it is assumed that the sample of observed means being tested, $m_1, m_2, m_3 \ldots mn$ have been drawn independently from n normal populations of true means $u_1, u_2, u_3 \ldots un$. Second, it is assumed that the standard error is unknown but that an estimate, Sm, is available. It is assumed that Sm is independent of the

[49] Ibid., 6.

observed means and is based on the number of degrees of freedom.[50]

3.3 DATA

The data that were analyzed were obtained from bulletins published quarterly by the Canadian Grain Commission. These bulletins are entitled 'Quality of Canadian Grain Exports'. The bulletins provide milling and baking quality data for red spring wheat cargoes exported from Canada by ship for a given quarter. The processing quality characteristics presented in the bulletins and employed in this study include: test weight, weight per 1000 kernels, wheat alpha-amylase activity, Falling Number value, moisture content, wheat protein content, wet gluten content, ash content, flour protein content, flour color, flour starch damage, flour alpha-amylase activity, amylograph peak viscosity, baking absorption, gassing power, loaf volume, bread appearance, crumb color, crumb texture, blend loaf volume, farinogram absorption,farinogram development time, extensigram length, extensigram maximum height, extensigram area, alveogram length, alveogram area, and alveograph W value(number of ergs). The data were derived from the analysis of composite samples prepared from samples representing individual cargoes exported during the given quarter. The bulletins present the data by grade, guaranteed protein content for No.1 C.W. and No.2 C.W., and export position(Atlantic or Pacific).

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[50] Ibid., 7.

TABLE 2

2. NO. 1 CANADA WESTERN RED SPRING WHEAT ATLANTIC COMPOSITES

Quality Parameter	NO. 1 C.W. Guaranteed Minimum Protein Content 14.5	13.5	12.5
WHEAT			
Test Weight, kg/hL	81.1	81.8	82.3
Weight per 1000 Kernels, g	27.7	28.7	30.6
Protein Content, %	14.7	13.7	12.6
Alpha-amylase Activity, units/g	2.5	3.7	3.2
Falling Number, s	445	425	445
Flour Yield, %	75.3	75.3	76.0
FLOUR			
Protein Content, %	14.2	13.2	12.4
Wet Gluten Content, %	41.7	38.0	34.8
Ash Content, %	0.49	0.50	0.50
Color, units	-0.2	-0.5	-0.4
Starch Damage, Farrand units	25	28	28
Alpha-amylase Activity, units/g	1.3	2.0	1.7
Amylograph Peak Viscosity, B.U.	670	590	595
Maltose Value, g/100 g	1.6	1.8	1.9
Baking Absorption, %	63	62	62
BREAD			
Loaf Volume, cm^3	965	870	805
Appearance	8.5	8.0	7.8
Crumb Structure	6.8-o	6.8-o	7.0-o
Crumb Color	6.8-d	6.5-dy	5.8-dy
Blend Loaf Volume, cm^3	765	720	685
FARINOGRAM			
Absorption, %	63.2	62.8	62.7
Development Time, min	5.25	4.25	4.00
EXTENSIGRAM			
Length, cm	22	22	21
Height at 5 cm, B.U.	290	290	280
Maximum Height, B.U.	520	500	450
Area, cm^2	150	145	130
ALVEOGRAM			
Length, mm	133	124	108
P (height x 1.1), mm	92	93	97
Area, cm^2	64	60	54
W, x 10^3 ergs	413	390	360

Source: Quality of Canadian Grain Exports, Quarterly Bulletin No. 227 Third Quarter, 1984-85, Canadian Grain Commission, Grain Research Laboratory Division.

Data for the first quarter of the 1975-76 crop year to the first quarter of the 1985-86 crop year were used. It should be noted that gaps in the data exist where particular grades were not exported during a particular period or certain tests were not implemented. Table 2 is a reproduction of a page of a recent C.G.C. Cargo Bulletin and provides an example of the type of data that will be analyzed in the following example.

3.4 EXAMPLE OF DUNCAN'S TEST

The following section provides an example of the Duncan's Test administered to one of the processing quality characteristics. The data used in the following example is the actual data for alpha amylase activity(ex Pacific). The data is formally summarized and presented in Table 3. It should be noted that no data exist for the period from the first quarter of 1975-76 to the first quarter of 1980-81 since the test was not administered by the C.G.C. The objective of the test will be to determine whether the means for each of the six grades (treatments) i.e. No.1 C.W.R.S. 14.5%, No.1 C.W.R.S. 13.5%, No.1 C.W.R.S.12.5%, No.2 C.W.R.S. 13.5%, No.2 C.W.R.S. 12.5% and No.3 C.W.R.S. are significantly different from one another.

The analysis of the alpha amylase activity data will follow the outline of the Duncan's Test described above. From the data in Table 3, the necessary statistics are derived

TABLE &ALPHA AMYLASE ACTIVITY DATA (EX PACIFIC)

Year/Quarter	1 CWRS 14.5%	1 CWRS 13.5%	1 CWRS 13.5%	2 CWRS 13.5%	2 CWRS 12.5%	3 CWRS
1980-81/1	.	2.1	2.7	.	4.2	18.0
1980-81/2	2.6	2.1	2.3	.	3.2	5.8
1980-81/3	1.8	1.7	2.0	.	2.6	6.4
1980-81/4	1.6	1.6	2.0	.	1.8	4.6
1981-82/1	1.1	1.8	2.1	0.7	3.1	5.9
1981-82/2	0.3	0.7	0.9	1.5	1.5	3.4
1981-82/3	0.8	1.1	1.2	2.0	1.6	5.5
1981-82/4	0.5	1.7	1.7	1.9	2.5	3.7
1982-83/1	1.0	1.2	1.0	2.0	2.5	4.7
1982-83/2	0	1.3	1.6	1.4	1.6	2.5
1982-83/3	.	1.0	1.3	2.2	1.8	2.0
1982-83/4	.	1.3	2.1	2.5	2.2	4.4
1983-84/1	.	1.2	1.5	2.2	2.4	4.6
1983-84/2	0.9	1.4	1.9	3.5	4.1	11.5
1983-84/3	1.3	1.8	2.3	4.9	4.8	6.8
1983-84/4	1.2	1.8	2.6	5.8	6.7	10.6
1984-85/1	1.1	1.3	1.7	2.1	2.0	7.5
1984-85/2	1.4	2.5	.	11.1	10.2	41.3
1984-85/3	0.9	0.9	.	12.5	2.7	63.2
1984-85/4	1.9	2.6	2.5	6.7	12.9	30.2
1985-86/1	11.9	1.9	1.9	4.7	6.5	28.2

Source: Quality of Canadian Grain Exports, Quarterly Bulletins Nos.194-234, Canadian Grain Commission, Grain Research Laboratory Division.

and presented in Table 4. In part a) of Table 4 the means of the six treatments are presented. Part b) of Table 4 lists the analysis of variance. The degrees of freedom are taken from the analysis of variance and are necessary to derive the significant studentized ranges from a table entitled "Significant Studentized Ranges For a 5% Level New Multiple Range Test."[51] The significant studentized ranges are listed in part c) of Table 4. Part d) of Table 4 calculates the standard deviation.

[51] Ibid, 4.

TABLE &WORKSHEET FOR DUNCAN'S TEST (ALPHA AMYLASE ACTIVITY,EX PACIFIC)

a)

grade	1CWRS 14.5%	1CWRS 13.5%	1CWRS 12.5%	2CWRS 13.5%	2CWRS 12.5%	3CWRS
mean	1.269	1.571	1.858	3.852	3.982	12.895

b)Analysis of Variance

Source	D.F.	M.S.
Model	5	394.49
Error	109	47.90

c)Significant Studentized Ranges

P:	(2)	(3)	(4)	(5)	(6)
	2.44	2.92	3.01	3.08	3.11

d)Standard Error

Sm= M.S.(Error)/D.F.(Model)

Sm= 47.90/5 = 3.09

e)Shortest Significant Ranges

P:	(2)	(3)	(4)	(5)	(6)
Rp:	8.55	9.24	9.33	9.54	9.73

f)Results

Treatment	Mean	Group
No.1 C.W.R.S. 14.5%	1.269	A
		A
No.1 C.W.R.S. 13.5%	1.571	A
		A
No.1 C.W.R.S. 12.5%	1.858	A
		A
No.2 C.W.R.S. 12.5%	3.852	A
		A
No.2 C.W.R.S. 13.5%	3.982	A
No.3 C.W.R.S.	12.895	B

(note:those means with common letter are not significantly different)

Having derived all of the necessary statistics, two final calculations are made. First, the significant studentized ranges are multiplied by the standard error to yield the shortest significant range. The shortest significant ranges are presented in part e) of Table 4. Finally, the shortest significant ranges are compared to the differences between the two means (part f).

Given the previously calculated means, the difference between means is significant if it exceeds the corresponding shortest significant range; otherwise the difference between the means is not significant. For example, because the means of No.1 C.W.R.S. 14.5% and No.3 C.W.R.S. represent the range of six means, the difference between the means must exceed the shortest significant range R=9.73 to be significant. In this case the difference between the means (11.626) does exceed the shortest significant range and the statistically different means are assigned to different groups(A for No.1 C.W.R.S. 14.5% and B for No.3 C.W.R.S.).

Chapter IV

RESULTS

This section presents, in summary form, the results of analyses of data for three grades, Nos.1,2 and 3 C.W.R.S. Grades Nos.1 and 2 C.W.R.S. are segregated according to protein content into levels of 14.5%,13.5%,12.5% and 13.5% and 12.5%, respectively. The segregation of Nos.1 and 2 C.W.R.S. by protein content expands the data base to six treatments- No.1 C.W.R.S. 14.5%, No.1 C.W.R.S. 13.5%, No.1 C.W.R.S. 12.5%, No.2 C.W.R.S. 13.5%, No.2 C.W.R.S. 12.5% and No.3 C.W.R.S. (Hence forth the six segregations will assume the statistical term "treatment" to facilitate reference to segregations within the same grade.) This arrangement allows for the comparison of treatments having the same grade but different protein content or alternatively, comparable protein content but different grade.

The Duncan's Test was used for each processing quality characteristic separately. Those treatments whose means are not significantly different were grouped together. For some characteristics, the difference was not significant; in such cases all treatments were grouped together. For characteristics for which each of the six means were significantly different, the treatments were grouped separately.

The Duncan's Test results are listed in Appendix 1 (p. 76). Analyzing each processing quality characteristic individually, as presented in Appendix 1, does not fully address the primary objective of this study. The limited significance drawn from evaluating the results of the characteristics individually relates to the end-use of wheat. Wheat is the primary ingredient for numerous end-products. Each end-use assigns a unique level of significance to each characteristic.[52] This precludes an individual evaluation of the characteristics and an ordinal ranking of the results.

Alternatively, the Duncan's Test results have been aggregated in Tables 5 and 6. These tables isolate one of the six treatments (grades and subgrades by protein content) against another and identifies those processing quality characteristics that prove to be significantly different between the two treatments. Each of the 15 possible combinations of treatments is addressed. The results from the Atlantic cargoes are presented in Table 5 and those for the Pacific cargoes in Table 6.

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[52] Pomeranz Wheat Chemistry and Technology p.202

4.1 ATLANTIC CARGO RESULTS

The comparison of treatments across grades(i.e. No.1 C.W.R.S. vs. No.2 C.W.R.S.) are presented in rows one through 11 of Table 5. Returning to the necessary condition being examined, all processing quality test results should be significantly different across grades for a grading system to be optimal, except of course, for grain and flour protein of grades segregated by the same protein content. Table 5 shows that of the 11 across-grade comparisons, the maximum number of significantly different processing quality characteristics proved to be 27 of a possible 31. This result was found for the comparison of the most extreme treatments, No.1 C.W.R.S. 14.5% vs. No.3 C.W.R.S. The least number of significantly different processing quality characteristics was found to be nine for the comparison of the treatments No.1 C.W.R.S. 12.5% vs. No.2 C.W.R.S. 12.5%.

For each of the six treatments, the opposing treatment corresponding to the minimum number of significantly different processing quality characteristics proved to be the treatment with the closest protein content. That is, the across-grade comparisons suggested that the number of different characteristics between treatments was directly correlated with the difference in protein content between those treatments. Twenty-one characteristics proved significantly different between No.1 C.W.R.S. 14.5% and No.2 C.W.R.S. 13.5%, only 12 between No.1 C.W.R.S. 13.5% and No.2 C.W.R.S.

Table 5 Results for Atlantic Cargoes

Comparison	Significantly Different Processing Quality Characteristics	Total Number
1)No.1 C.W.R.S. 14.5% vs. No.2 C.W.R.S. 13.5%	Flour Protein, Wet Gluten, Flour Amylogragh Peak Viscosity, Gassing Power, Flour Alpha-Amylase Activity, Loaf Volume, Test Weight, Flour Color, Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Flour Absorption, Extensigram Maximum Height, Number of Ergs, Wheat Protein	21
2)No.1 C.W.R.S. 14.5% vs. No.2 C.W.R.S. 12.5%	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Flour Alpha-Amylase Activity, Loaf Volume, Test Weight, Wheat Alpha Amylase, Moisture, Falling Number, Crumb Color, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Extensigram Length, Flour Absorption, Alveogram Height, Extensigram Maximmum Height, 1000-Kernel Weight, Farinogram Absorption, Number of Ergs, Wheat Protein	24
3)No.1 C.W.R.S. 14.5% vs. No.3 C.W.R.S.	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Flour Alpha-Amylase Activity, Loaf Volume, Test Weight, Flour Color, Wheat Alpha-Amylase Activity, Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Extensigram Length, Flour Absorption, Alveogram Height, Starch Damage, Extensigram Maximum Height, Flour Ash, 1000-Kernel Weight, Crumb Texture, Wheat Protein	27
4)No.1 C.W.R.S. 13.5% vs. No.2 C.W.R.S. 13.5%	Flour Amylograph Peak Viscosity, Gassing Power, Flour Alpha-Amylase Activity, Loaf Volume, Test Weight, Flour Color, Moisture, Falling Number, Wheat Flour Yield, Extensigram Maximum Height, Flour Ash, Wheat Protein	12
5)No.1 C.W.R.S. 13.5 vs. No.2 C.W.R.S. 12.5%	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Flour Alpha-Amylase Activity, Loaf Volume, Test Weight, Flour Color, Wheat Alpha-Amylase Activity, Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Flour Absorption, Alveogram Height, Extensigram Maximum Height, 1000-Kernel Weight	22
6)No.1 C.W.R.S. 13.5 vs. No.3 C.W.R.S.	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Flour Alpha-Amylase Activity, Loaf Volume, Test Weight, Flour Color, Wheat Alpha-Amylase Activity, Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Flour Absorption, Alveogram Height, Extensigram Maximum Height, Flour Ash, Starch Damage, Extensigram Length, Wheat Protein	25
7)No.1 C.W.R.S. 12.5% vs. No.2 C.W.R.S. 13.5%	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Loaf Volume, Test Weight, Flour Color, Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Length, Flour Absorption, Alveogram Height, Starch Damage, 1000-Kernel Weight, Extensigram Height, Wheat Protein	23

Table 5 (cont'd)

8)No.1 C.W.R.S. 12.5% vs. No.2 C.W.R.S. 12.5%	Flour Amylograph Peak Viscosity, Gassing Power, Test Weight, Flour Color, Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Extensigram Maximum Height, Wheat Protein	9
9)No.1 C.W.R.S. 12.5% vs. No.3 C.W.R.S.	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Flour Alpha-Amylase Activity, Loaf Volume, Test Weight, Flour Color, Wheat Alpha-Amylase Activity,Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Flour Absorption, Extensigram Maximum Height, Flour Ash, Farinogram Absorption, Wheat Protein	18
10)No.2 C.W.R.S. 13.5% vs. No.3 C.W.R.S.	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Four Alpha Amylase Activity, Loaf Volume, Test Weight, Flour Color, Wheat Alpha-Amylase Activity, Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Extensigram Length, Alveogram Height, Starch Damage, Flour Ash, 1000-Kernel Weight, Farinogram Absorption, Wheat Protein	24
11)No.2 C.W.R.S. 12.5% vs. No.3 C.W.R.S.	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Four Alpha Amylase Activity, Loaf Volume, Test Weight, Flour Color, Wheat Alpha-Amylase Activity, Falling Number, Crumb Color, Wheat Flour Yield, Flour Absorption, Flour Ash,Farinogram Absorption, Wheat Protein	16
12)No.1 C.W.R.S. 14.5% vs. No.1 C.W.R.S. 13.5%	Flour Protein, Wet Gluten, Gassing Power, Loaf Volume, Test Weight, Moisture, Falling Number, Crumb Color, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Flour Absorption, Alveogram Height, 1000-Kernel Weight, Wheat Protein	16
13)No.1 C.W.R.S. 14.5% vs. No.1 C.W.R.S. 12.5%	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Loaf Volume, Test Weight, Flour Color, Moisture, Falling Number, Crumb Color, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Extensigram Length, Flour Absorption, Number of Ergs, Alveogram Length, Starch Damage, 1000-Kernel Weight, Farinogram Absorption, Wheat Protein	23
14)No.1 C.W.R.S. 13.5% vs. No.1 C.W.R.S. 12.5%	Flour Protein, Wet Gluten, Gassing Power, Loaf Volume, Crumb Color, Bread Appearance Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Extensigram Length, Flour Absorption, Alveogram Height, Starch Damage, Wheat Protein	15
15)No.2 C.W.R.S. 13.5% vs. No.2 C.W.R.S. 12.5%	Flour Protein, Wet Gluten, Loaf Volume, Test Weight, Flour Color, Moisture, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Extensigram Length, Flour Absorption, Alveogram Height, Starch Damage, Extensigram Maximum Height, 1000-Kernel Weight, Crumb Color, Wheat Protein	19

13.5%, just nine between No.1 C.W.R.S. 12.5% and No.2 C.W.R.S. 12.5% and 16 between No.2 C.W.R.S. 12.5% and No.3 C.W.R.S.

Besides maximizing variation in quality across grades, a grading system should minimize variation within grades. Comparisons 12 through 15 list those comparisons of treatments of the same grade(i.e. No.1 C.W.R.S.14.5% vs. No.1 C.W.R.S. 13.5%). Table 5 shows that for No.1 C.W.R.S. 14.5% and No.1 C.W.R.S. 13.5% there were 16 of a possible 31 significantly different quality processing characteristics, 23 between No.1 C.W.R.S. 14.5% and No.1 C.W.R.S. 12.5%, 15 between No.1 C.W.R.S. 13.5% and No.1 C.W.R.S. 12.5% and 19 between No.2 C.W.R.S. 13.5% and No.2 C.W.R.S. 12.5%. In summary, these results indicate that for some comparisons of treatments there is less variation across grades than within grades in terms of the number of significantly different processing quality characteristics. For example, within No.1 C.W.R.S. there were 24 significantly different processing quality characteristics between No.1 C.W.R.S. 14.5% and No.1 C.W.R.S. 12.5% while across No.1 C.W.R.S. and No.2 C.W.R.S. there were just nine for No.1 C.W.R.S. 12.5% and No.2 C.W.R.S. 12.5%. Obviously, protein content is a key characteristic for discriminating parcels of wheat in terms of processing quality.

4.2 PACIFIC CARGO RESULTS

The comparison of those treatments having different grades are presented in sections one through 11 of Table 6. The maximum number of significantly different processing quality characteristics was found to be 29 for two different comparisons, No.1 C.W.R.S. 14.5% vs. No.3 C.W.R.S. and No.1 C.W.R.S. 13.5% vs. No.3 C.W.R.S. The above comparisons also proved to be the two comparisons exhibiting the greatest difference between average protein contents. Referring to Appendix 1, No.1 C.W.R.S. 14.5% proved to have the highest average protein content(14.6), No.1 C.W.R.S. 13.5% the second highest(13.7) and No.3 C.W.R.S. the lowest(12.6) of the six treatments. These observations lend support to the relationship derived from the Atlantic results that suggested that a number of processing quality characteristics are related to grade and the number of different characteristics between any two grades is partially related to the difference in protein content between the two grades e.g. the two comparisons with the greatest difference in protein content also proved to have the largest number of significantly different characteristics.

Those comparisons of treatments found to have the least number of significantly different characteristics were No.1 C.W.R.S. 13.5% vs. No.2 C.W.R.S. 13.5% and No.1 C.W.R.S. 12.5% vs. No.2 C.W.R.S. 12.5%. Each of the above comparisons had only ten characteristics that were significantly

Table 6 Results for Pacific Cargoes

Comparison	Significantly Different Processing Quality Characteristics	Total Number
1)No.1 C.W.R.S. 14.5% vs. No.2 C.W.R.S. 13.5%	Wheat Protein, Flour Protein, Wet Gluten,Crum Color, Loaf Volume, Gassing Power, Moisture, Flour Amylogragh Peak Viscosity, Alveogram Length, Bread Appearance, Falling Number, Farinogram Development Time, Blend Loaf Volume, Flour Absorption	14
2)No.1 C.W.R.S. 14.5% vs. No.2 C.W.R.S. 12.5%	Wheat Protein, Flour Protein, Wet Gluten, Crum Color, Loaf Volume, Gassing Power, Moisture, Flour Amylograph Peak Viscosity, Alveogram Length, Bread Appearance, Falling Number, Farinogram Development Time, Blend Loaf Volume, Flour Absorption, Test Weight, Extensigram Length, Starch Damage, Alveogram Height, 1000-Kernel Weight, Extensigram Maximum Height, Number of Ergs. Flour Yield	22
3)No.1 C.W.R.S. 14.5% vs. No.3 C.W.R.S.	Wheat Protein, Flour Protein, Wet Gluten, Crum Color, Loaf Volume, Gassing Power, Moisture, Flour Amylograph Peak Viscosity, Flour Color, Alveogram Length, Bread Appearance, Test Weight, Falling Number, Wheat Flour Yield, Farinogram Development Time, Blend Loaf Volume, Extensigram Area, Wheat Alpha-Amylase Activity, Extensigram Maximum Height, Extensigram Length, Flour Alpha-Amylase Activity, Starch Damage, Number of Ergs, Alveogram Area, Alveogram Height, Flour Absorption, 1000-Kernel Weight, Flour Ash, Crumb Texture	29
4)No.1 C.W.R.S. 13.5% vs. No.2 C.W.R.S. 13.5%	Flour Amylograph Peak Viscosity, Gassing Power, Extensigram Height, Extensigram Area, Test Weight, Flour Color, Moisture, Falling Number, Extensigram Maximum Height, Flour Ash,	10
5)No.1 C.W.R.S. 13.5 vs. No.2 C.W.R.S. 12.5%	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Gassing Power, Moisture, Flour Amylograph Peak Viscosity, Flour Color, Alveogram Length, Bread Appearance, Test Weight, Falling Number, Wheat Flour Yield, Farinogram Development Time, Blend Loaf Volume, Extensigram Area, Extensigram Maximum Height, Starch Damage, Number of Ergs, Alveogram Area, Flour Absorption	22
6)No.1 C.W.R.S. 13.5 vs. No.3 C.W.R.S.	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Gassing Power, Moisture, Flour Amylograph Peak Viscosity, Flour Color, Alveogram Length, Bread Appearance, Test Weight, Falling Number, Wheat Flour Yield, Farinogram Development Time, Blend Loaf Volume, Extensigram Area, Extensigram Maximum Height, Starch Damage, Number of Ergs, Alveogram Area, Wheat Alpha-Amylase Activity, Extensigram Height, Extensigram Length, Flour Alpha-Amylase Activity, Alveogram Height, 1000-Kernel Weight, Flour Ash,Crumb Texture	29
7)No.1 C.W.R.S. 12.5% vs. No.2 C.W.R.S. 13.5%	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Moisture, Flour Amylograph Peak Viscosity, Flour Color, Alvrogram Length, Test Weight, Falling Number, Blend Loaf Volume, Extensigram Length, 1000-Kernel Weight, Extensigram Height	15

Table 6 (cont'd)

8)No.1 C.W.R.S. 12.5% vs. No.2 C.W.R.S. 12.5%	Flour Amylograph Peak Viscosity, Gassing Power, Test Weight, Flour Color,Wheat Protein, Falling Number, Wheat Flour Yield, Extensigram Height, Extensigram Area, Flour Protein	10
9)No.1 C.W.R.S. 12.5% vs. No.3 C.W.R.S.	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Gassing Power, Moisture, Flour Amylograph Peak Viscosity, Flour Color, Alveogram Length, Bread Appearance, Test Weight, Falling Number, Wheat Flour Yield, Farinogram Development Time, Blend Loaf Volume, Extensigram Area, Wheat Alpha-Amylase Activity, Extensigram Maximum Height, Flour Alpha-Amylase Activity, Starch Damage, Farinogram Absorption, Alveogram Area, Extensigram Height, Flour Ash, Crumb Texture	26
10)No.2 C.W.R.S. 13.5% vs. No.3 C.W.R.S.	Flour Protein, Wet Gluten, Flour Amylograph Peak Viscosity, Gassing Power, Four Alpha Amylase Activity, Loaf Volume, Test Weight, Flour Color, Wheat Alpha-Amylase Activity, Moisture, Falling Number, Crumb Color, Wheat Flour Yield, Bread Appearance, Blend Loaf Volume, Alveogram Length, Farinogram Development Time, Extensigram Area, Extensigram Length, Alveogram Height, Starch Damage, Flour Ash, 1000-Kernel Weight, Farinogram Absorption, Crumb Texture	25
11)No.2 C.W.R.S. 12.5% vs. No.3 C.W.R.S.	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Gassing Power, Moisture, Flour Amylograph Peak Viscosity, Flour Color, Alveogram Length, Bread Appearance, Test Weight, Falling Number, Wheat Flour Yield, Farinogram Development Time, Blend Loaf Volume, Extensigram Area, Wheat Alpha-Amylase Activity, Extensigram Maximum Height, Extensigram Length, Flour Alpha-Amylase Activity, Starch Damage, Flour Ash, Crumb Texture	24
12)No.1 C.W.R.S. 14.5% vs. No.1 C.W.R.S. 13.5%	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Moisture, Flour Color, Alveogram Length, Bread Appearance, Test Weight, Falling Number, Blend Loaf Volume, Extensigram Maximum Height, Extensigram Length, Alveogram Height, Flour Absorption, 1000-Kernel Weight, Extensigram Height	18
13)No.1 C.W.R.S. 14.5% vs. No.1 C.W.R.S. 12.5%	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Gassing Power, Moisture, Flour Amylograph Peak Viscosity, Flour Color, Alveogram Length, Bread Appearance, Test Weight, Falling Number, Farinogram Development Time, Blend Loaf Volume, Extensigram Length, Starch Damage, Alveogram Height, Flour Absorption, 1000-Kernel Weight, Extensigram Height	21
14)No.1 C.W.R.S. 13.5% vs. No.1 C.W.R.S. 12.5%	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Gassing Power, Moisture, Alveogram Length, Bread Appearance, Farinogram Development Time, Blend Loaf Volume, Extensigram Area, Starch Damage, Flour Absorption, 1000-Kernel Weight	15
15)No.2 C.W.R.S. 13.5% vs. No.2 C.W.R.S. 12.5%	Wheat Protein, Flour Protein, Wet Gluten, Crumb Color, Loaf Volume, Gassing Power, Moisture, Alveogram Length, Farinogram Development Time, Extesigram Area, Extensigram Length, Flour Absorption, 1000-Kernel Weight	13

different. Besides minimizing the number of different characteristics, the above two comparisons proved to be the most similar of the 15 comparisons in terms of protein content. Again, this observation lends support for a correlation between the number of different characteristics and the difference in protein content between the treatments being compared.

Comparisons 12 through 15 again list those treatments that have the same grade but different protein contents. Since the comparisons are between treatments of the same grade,theoretically there should not be any characteristics that are different between the treatments. However, as with the Atlantic cargo results, all inter-grade comparisons proved to have a number of different characteristics. For No.1 C.W.R.S. 14.5% vs. No.1 C.W.R.S. 13.5% there were 18 different characteristics, 21 for No.1 C.W.R.S. 14.5% vs. No.1C.W.R.S. 12.5%, 15 between No.1 C.W.R.S. 13.5% vs. No.1 C.W.R.S. 12.5% and 13 between No.2 C.W.R.S. 13.5% vs. No. C.W.R.S. 12.5%.

The Atlantic and Pacific results were comparable, in general. Both sets of results supported two crucial observations. The first observation deals with the pursuit of the primary objective - whether all grades are significantly different in all processing quality characteristics. Both sets of data rejected this hypothesis. This observation was supported by the fact that all inter-grade comparisons shared processing quality characteristics that were not significantly different. In fact some treatments shared fewer similar processing quality characteristics with opposing treatments having the same grade than treatments of a different grade.

The second crucial observation supported by both the Pacific and Atlantic results concerns the influence of protein content. For both sets of results, the number of significantly different characteristics between any two treatments appeared related to the difference in protein content between the two treatments. This observation was supported by the finding that for each treatment the opposing treatment that minimized the number of different characteristics also minimized the difference in protein content between the two treatments. The results obtained here underscore the well-known importance of protein content to processing quality of bread wheat and the need to include this characteristic in a wheat grading system.

Chapter V

DISCUSSION

The first observation that will be addressed concerns the effect of protein content. Protein content of wheat has long been recognized as a good index of its breadmaking quality. In fact, it has been suggested that, in the absence of actual baking tests, protein content is the best single test of breadmaking potential.[53] Support for this argument is quite straightforward. Protein content is a reliable index of breadmaking potential because many other processing quality characteristics are related to it.[54] Furthermore, protein quality and, to some extent, content in the cultivars of the C.W.R.S. class are controlled by selection during breeding of new varieties. In practice, the U.S. trade has recognized this relationship to the extent that protein content is relied upon as the market index of the processing quality characteristics for both Hard Red Spring and Hard Red Winter Wheats.[55] In Australia, protein content, after variety, discriminates the three milling

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[53] Pomeranz in Dunne, William Theoretical and Practical Considerations In The Segregation Of Canadian Wheat By Protein Content, p.18

[54] Ibid., 18.

[55] John D. Hyslop. Price-Quality Relationships in Spring Wheat. Univ. Minn. Ag. Exp. Sta. Tech Bul. 267, 3.

grades, Prime Hard, Hard and Australian Standard White.[56]

Recognition of the protein content-processing quality relationship by the grain trade has been the result of an evolution of a considerable amount of research yielding comparable results. Dunne[57] reviewed a number of studies dating back to 1931 which support a linear relationship between loaf volume(considered as the best single index of baking quality) and protein content. Larmour[58] first supported this relationship by obtaining a correlation coefficient of 0.9 between loaf volume and protein content in 1931. His data led him to conclude that a linear relationship existed between the two variables within the range of 7% to 15.9% protein. McCalla replicated Larmour's findings by reproducing a correlation coefficient of 0.9. McCalla[59] extended Larmour's work and concluded that the increase in loaf volume per unit of protein was specific or characteristic of each variety. A study by Finney in 1948 extended the work by both Larmour and McCalla. Finney used different varieties

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[56] W. Bushuk, "Wheat Identification and Segregation in Canada and Australia" in Wheat Production in Canada ed. A.E. Slinbard and D.B. Fowler,603-613, University of Saskatchewan, Sk, 1986.

[57] Dunne, W. "Theoretical and Practical Considerations In The Segregation Of Canadian Wheat By Protein Content",(Ph.D. Diss. University of Manitoba, 1971),18.

[58] R.K. Larmour, "The relation of wheat protein to baking quality.II. Saskatchewan hard red wheat crop of 1929." Cereal Chem. 8 (1931):179-189.

[59] A.G. McCalla and R. Newton, "Effect of Frost on Wheat at Progressive Stages of Maturity. II. Composition and Biochemical Properties of Grain and Flour." Can. J. Research 13 (1935): 1-31.

of wheat each with its own characteristic protein quality and concluded that a linear relationship existed between protein content and loaf volume over the 7% to 20% protein range. Finney also concluded that the slope of the regression line was a varietal characteristic. These conclusions were reinforced in a subsequent study by Bushuk et al in 1969.[60]

Besides the relationship between protein content and loaf volume, the relationships between protein content and the rheological properties of dough have further influenced the relative significance placed on protein content by end-users. The rheological properties of dough are most often evaluated using the farinograph, alveogragh and extensograph. In 1944 Aitken et al studied the effect of protein content on these three measurements and concluded that a direct correlation existed between protein content and parameters obtained with the three instruments except for the alveogram height in which case an inverse relationship was obtained.[61]

With respect to the relationships described above, a technical explanation does little to advance the primary objective of this study. Therefore, although the acknowl-

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[60] W. Bushuk,K.G. Briggs and L.H. Shebeski, Protein Quantity and Quality as Factors in the Evaluation of Bread Wheats. Can. J. Plant Sci. 49 (1969): 113-122.

[61] T.R.Aitken,M.H. Fisher and J.A. Anderson. "Effect of Protein Content on Farinograms,Extensograms and Alveograms." Cereal Chem (1944)21:465-488.

edgement of the relationship between protein content and certain processing quality characteristics is relevant to the difference in characteristics between grades, the technical aspect will not be pursued further. For a complete technical review the reader could refer to Pomeranz.

The relationships between protein content and processing quality characteristics obtained in this study are generally consistent with published results. The results for the Atlantic cargoes showed that for the comparison of treatments No.1 C.W.R.S. 13.5% vs. No.2 C.W.R.S. 13.5% only extensigram maximum height proved significantly different of all rheological and bread volume tests. The same observation was made for the comparison of treatments No.1 C.W.R.S. 12.5% vs. No.2 C.W.R.S. 12.5%. At the opposite end of the spectrum, the treatments having the most divergent protein contents, No.1 C.W.R.S. 14.5% vs. No.3 C.W.R.S., yielded six significantly different rheological properties as well as both loaf volume and blend loaf volume.

For the Pacific cargoes results, the comparison of those treatments of different grades segregated by the same protein content yielded slightly more significantly different rheological properties. For No.1 C.W.R.S. 13.5% vs. No.2 C.W.R.S. 13.5%, extensigram height, extensigram maximum height and extensigram area proved to be significantly different. For No.1 C.W.R.S. 12.5% vs. No.2 C.W.R.S. 12.5% only extensigram height and extensigram area proved to be significantly different. Loaf volume and blend loaf volume were not significantly different for either comparison. At the extreme, No.1 C.W.R.S. 14.5% vs. No.3 C.W.R.S. exhibited a significant difference in a total of eight different rheological properties.

These results may be explained in part by the relationship between protein and certain processing quality characteristics. Where the results indicate few significantly different quality processing characteristics, it can be concluded that the similarities between the rheological properties and loaf volume can be attributed in part to comparable protein contents between the two treatments. Likewise, where many characteristics prove to be significantly different between treatments, the differences between the rheological properties and loaf volume may be attributed to the difference in protein content between the two treatments.

The foregoing analysis regarding the relationship between protein content and processing quality characteristics directly concerns the primary objective of this study. Given the known relationships between protein and both the rheological and loaf volume characteristics, it may be argued that the horizontal presentation of protein content is intended to offer different grades of wheat having comparable rheological and loaf volume characteristics. Therefore, where different treatments at the same protein content resulted in a large number of characteristics that were not different, it may be argued that the rheological and bread volume tests exaggerate the extent to which the grades are the same in terms of processing characteristics.

In order to approach the primary objective, acknowledgement of the above argument serves to shift attention to those processing characteristics that are not related to protein content. These include alpha-amylase activity, falling number, ash content, starch damage, baking absorption, gassing power, bread appearance, crumb color, crumb texture, flour yield, wet gluten content, amylograph peak viscosity and weight per thousand kernels. Of these processing characteristics, only the results for amylograph peak viscosity proved significantly different in the comparison of all treatments of different grades for both the Atlantic and Pacific results. That is, for all processing characteristics (except for amylograph peak viscosity) there was at least one across grade comparison(either Atlantic,Pacific or both) which produced no significant difference being found.

The results presented in this thesis are sufficient to resolve the primary objective of this study. In the literature review it was found that it is only necessary for two grades not to possess exactly the same characteristics if any pricing efficiency is forthcoming at all. The results of this study indicate that the Canadian wheat grading system satisfies this condition. As stated above, amylograph peak viscosity proved significantly different for the comparison of all treatments having different grades. This feature of the Canadian wheat grading system provides end-users with assurance that amylograph peak viscosity are significantly different. Thus, it may be concluded that the Canadian wheat grading system meets the objective of enhancing pricing efficiency.

However, the results of this study indicate that the Canadian wheat grading system does not approach optimality. An optimal grading system requires that differences between grades be maximized, or alternatively that overlapping of characteristics across grades be minimized.[62] Clearly, this study showed that the degree of overlapping of processing characteristics across grades is extensive. Accordingly, there exists much potential to increase the pricing efficiency component of the Canadian wheat grading system.

The above conclusions may be extended to support the hypothesis that an insignificant difference in processing characteristics exists between grades as a result of an insignificant relationship between the grading standards for C.W.R.S. wheat and the processing characteristics. Although this study does not provide objective evidence to support this hypothesis, it is supported intuitively. First, there is a significant difference between grades in terms of grading standards (this must be so since the grades are defined by the standards). Second, there is not a significant dif-

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[62] Williams and Stout Economics of the Livestock-Meat Industry 486.

ference between grades in terms of processing characteristics (except and amylograph peak viscosity). Given the above relationships, it can be concluded that the grading standards are two separate events which may be described statistically as follows:[63]

$$\frac{P(\text{grading standards})}{(\text{processing criteria})} = P(\text{grading standards})$$

or

$$\frac{P(\text{processing criteria})}{(\text{grading standards})} = P(\text{processing criteria})$$

This relationship may be interpreted as meaning that the occurrence of one event does not influence the probability of the other event. Specifically, the application of the grading standards to C.W.R.S. wheat does not influence the probability that the processing quality characteristics will differ by grade. For example, the application of test weight as a grading standard will not influence the probability that two samples will differ in terms of flour yield. Finally, it may be concluded that the processing characteristics and grading standards are two independent events.

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[63] W. Mendenhall, Introduction to Probability and Statistics, (Belmont, California, Wadsworth Publishing Company Inc., 1979)

At this point of the discussion its direction should pursue suggestions for potential improvements of the grading system. However, while the results of this study suggest that changes to the grading system are necessary, they offer no immediate solutions.

However, the results of this study do lend direction to further research. With respect to the model developed by Farris and presented in Chapter II, it is the rectangular area CC'EE' that is of relevance to this study. The results of this study indicate that there is an area comparable to CC'EE' that is available to the Canadian wheat grading system. The present grading system is clearly below line EE', the optimal scenario, if only for the reason that there is not a significant difference of processing characteristics between grades.

It is not clear, however, that an area comparable to OC'D' is available to the Canadian wheat grading system. This area is characterized by improvements over the present grading system that are at a cost that is affordable to the end-users. While it is apparent that there is room for improvement to the wheat grading system, the costs of such improvements are unknown. According to Farris, potential profits gained through product differentiation should initiate research into the feasability of gaining area OC'D'. Finally, the results of this study have served to lend direction to the evolution of the wheat grading system.

Chapter VI

SUMMARY, CONCLUSIONS AND IMPLICATIONS

6.0.1 Summary

This study was initiated to investigate the hypothesis that an insignificant relationship existed between the grades of CWRS wheat in terms of the processing quality characteristics that are important to end-users. The significance of the above hypothesis concerns one of the two objectives of a grading system, that of enhanced pricing efficiency.

The literature review served two purposes. First, it reviewed a series of economic models which proved that a significant difference in processing characteristics between grades was a necessary condition for a grading system to enhance pricing efficiency. Second, the literature review revealed a void of research directly pertaining to the difference of processing characteristics between grades of C.W.R.S. wheat. As an alternative, studies regarding the relationship between the grading standards of C.W.R.S. wheat and its processing characteristics were reviewed. Finally it was concluded that the results of the literature review warranted research carried out in this study.

The approach consisted of two steps. First, results of the processing characteristics for Nos. 1,2 and 3 C.W.R.S. were obtained and tabulated by grade. Second, the data were subjected to a statistical test referred to as a Duncan's Test.

6.0.2 Conclusions

The results of the Duncan's Test indicated that for no comparison of treatments of different grades were all processing characteristics significantly different. Likewise, for no comparison of treatments of the same grade and different protein content (e.g. No. 1 C.W.R.S. 14.5% vs. No.1 C.W.R.S. 13.5%) were all of the processing characteristics the same. In fact it was found that in some cases the comparison treatments of different grades were found to be more similar (strictly in terms of the number of processing characteristics) than were treatments of the same grade. In other words, the present grading system does not approach optimality. These results were explained in part by the relationship between protein content and the rheological properties and bread volume results. For the comparison of treatments of different grades and comparable protein content, the similarity between the treatments was a result of the relationship between protein content and the rheological and bread volume properties. Likewise, for the comparison of treatments of the same grade and different protein content, the differences were in part due to the same relationship between protein content and the rheological and bread volume characteristics. Finally, the above results support the conclusion that protein content may be better served as a grading standard than to segregate grades.

Exclusion of the rheological and bread volume results still left a large degree of overlapping of processing characteristics across grades. Accordingly, it was concluded that the present grading system fails to enhance pricing efficiency to the optimal extent. End-users are provided little assurance that the processing characteristics important to them will differ according to grade. The grading system fails to enhance the end-users knowledge of the processing characteristics and ultimately resources may be allocated improperly.

Finally, it was concluded that an insignificant difference between grades in terms of processing characteristics simply reflected a poor relationship between the grading standards and the processing quality characteristics themselves.

6.0.3 Implications

Achieving the primary objective has raised a number of implications. The first implication concerns the relationship between protein content and the processing quality characteristics. In discussing the results it was concluded that protein content was related to a number of processing quality characteristics. Support for this conclusion was drawn from comparisons of treatments of different grades and comparable protein content having relatively few significantly different processing characteristics. Given the relationship between protein content and the processing quality characteristics and the fact that it is already administered throughout the marketing chain, there appears justification for research into the implementation of protein content as a grading standard.

The second implication drawn from this study concerns the comparison of protein content between the Pacific and Atlantic data. Given that protein content is inversely related to precipitation and annual precipitation varies from region to region across Western Canada, it is plausible for protein content to be significantly different within the same protein segregation for Atlantic exports vs. Pacific exports. For example, the protein content of 1 C.W.R.S. 14.5% ex Pacific may be significantly different from 1 C.W.R.S. 14.5% ex Atlantic assuming that each port draws from different regions. Having determined that there is a relationship between protein content and certain processing quality characteristics, the above implication suggests that those characteristics related to protein content may differ between ports. The variation of processing quality characteristics between ports, then, is a potential topic for further research.

A third implication drawn from this study concerns the orientation of any future changes to the grading system. The present system employs a vertical orientation which implies a decreasing level of quality from No. 1 C.W.R.S. to Canada Feed. However, in the case of wheat the advantage of a vertical system as opposed to an horizontal system is not clear. Given that Canadian wheat is used for a variety of end-products, an horizontal system presenting only a difference in processing quality characteristics between grades may be more appropriate.

Extending the concept of an horizontal system has implications for the usefulness of variety as a grading standard. Presently, new varieties must compare to a given standard (Neepawa). This effectively restricts the introduction of varieties having limited breadmaking potential but which nonetheless are demanded by end-users. The inclusion of variety as a grading standard may be responsible for inhibiting the allocation of resources between what is demanded and what is produced. That is, the presence of variety as a grading standard may serve to block the communication system that signals the preferences of consumers back to the producers. Finally, the effect of variety as a grading standard and its effect on the orientation of the present grading system is deserving of further research.

APPENDIX 1

Duncan's Grouping Results

Note: Those treatments with the same letter are not significantly different.

Wheat

Test Weight, kg/hl

Atlantic Results

Treatment		Grouping
No.1 C.W.R.S.	12.5%	A
		A
No.1 C.W.R.S.	13.5%	A
No.1 C.W.R.S.	14.5%	B
No.2 C.W.R.S.	12.5%	C
No.2 C.W.R.S.	13.5%	D
No.3 C.W.R.S.		E

Pacific Results

Treatment		Grouping
No.1 C.W.R.S.	12.5%	A
		A
No.1 C.W.R.S.	13.5%	A
No.1 C.W.R.S.	14.5%	B
		B
No.2 C.W.R.S.	13.5%	B
		B
No.2 C.W.R.S.	12.5%	B
No.3 C.W.R.S.		C

Weight per 1000 Kernels, g

Atlantic Results

Treatment					
No.2 C.W.R.S.	12.5%	A			
		A			
No.1 C.W.R.S.	12.5%	A	B		
		A	B		
No.3 C.W.R.S.		A	B	C	
			B	C	
No.1 C.W.R.S.	13.5%		B	C	
				C	
No.2 C.W.R.S.	13.5%			C	D
					D
No.1 C.W.R.S.	14.5%				D

Pacific Results

Treatment			
No.3 C.W.R.S.		A	
		A	
No.2 C.W.R.S.	12.5%	A	
		A	
No.1 C.W.R.S.	12.5%	A	
No.1 C.W.R.S.	13.5%	B	
		B	
No.2 C.W.R.S.	13.5%	B	C
			C
No.1 C.W.R.S.	14.5%		C

Flour Yield

Atlantic Results

Treatment			
No.1 C.W.R.S.	13.5%	A	
		A	
No.1 C.W.R.S.	12.5%	A	
		A	
No.1 C.W.R.S.	14.5%	A	B
			B
No.2 C.W.R.S.	12.5%		B
			B
No.2 C.W.R.S.	13.5%		B
No.3 C.W.R.S.		C	

Pacific Results

Treatment			
No.1 C.W.R.S.	13.5%	A	
		A	
No.1 C.W.R.S.	12.5%	A	
		A	
No.2 C.W.R.S.	13.5%	A	B
		A	B
No.1 C.W.R.S.	14.5%	A	B
			B
No.2 C.W.R.S.	12.5%		B
No.3 C.W.R.S.		C	

<u>Alpha-amylase Activity, units/g</u>

No.3 C.W.R.S.		A		No.3 C.W.R.S.		A
No.2 C.W.R.S.	12.5%	B		No.2 C.W.R.S.	13.5%	B
		B				B
No.2 C.W.R.S.	13.5%	B	C	No.2 C.W.R.S.	12.5%	B
		B	C			B
No.1 C.W.R.S.	12.5%	B	C	No.1 C.W.R.S.	12.5%	B
		B	C			B
No.1 C.W.R.S.	13.5%	B	C	No.1 C.W.R.S.	13.5%	B
			C			B
No.1 C.W.R.S.	14.5%		C	No.1 C.W.R.S.	14.5%	B

<u>Protein Content</u>

No.1 C.W.R.S.	14.5%	A	No.1 C.W.R.S.	14.5%	A
No.2 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	13.5%	B
					B
No.1 C.W.R.S.	13.5%	C	No.2 C.W.R.S.	13.5%	B
No.3 C.W.R.S.		D	No.2 C.W.R.S.	12.5%	C
No.2 C.W.R.S.	12.5%	E	No.1 C.W.R.S.	12.5%	D
		E			
No.1 C.W.R.S.	12.5%	E	No.3 C.W.R.S.		E

<u>Falling Number,s</u>

No.1 C.W.R.S.	14.5%	A	No.1 C.W.R.S.	14.5%	A
No.1 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	13.5%	B
		B			B
No.1 C.W.R.S.	12.5%	B	No.1 C.W.R.S.	12.5%	B
No.2 C.W.R.S.	13.5%	C	No.2 C.W.R.S.	13.5%	C
		C			C
No.2 C.W.R.S.	12.5%	C	No.2 C.W.R.S.	12.5%	C
No.3 C.W.R.S.		D	No.3 C.W.R.S.		D

Moisture, %

No.3 C.W.R.S.		A	No.3 C.W.R.S.		A
		A			
No.2 C.W.R.S.	12.5%	A	No.2 C.W.R.S.	12.5%	B
No.2 C.W.R.S.	13.5%	B	No.2 C.W.R.S.	13.5%	C
No.1 C.W.R.S.	12.5%	C	No.1 C.W.R.S.	12.5%	D
		C			
No.1 C.W.R.S.	13.5%	C	No.1 C.W.R.S.	13.5%	E
No.1 C.W.R.S.	14.5%	D	No.1 C.W.R.S.	14.5%	F

Flour

Protein Content

No.1 C.W.R.S.	14.5%	A	No.1 C.W.R.S.	14.5%	A
No.2 C.W.R.S.	13.5%	B	No.2 C.W.R.S.	13.5%	B
		B			B
No.1 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	13.5%	B
No.3 C.W.R.S.		C	No.2 C.W.R.S.	12.5%	C
No.2 C.W.R.S.	12.5%	D	No.1 C.W.R.S.	12.5%	D
		D			
No.1 C.W.R.S.	12.5%	D	No.3 C.W.R.S.		E

Wet Gluten Content, %

No.1 C.W.R.S.	14.5%	A	No.1 C.W.R.S.	14.5%	A
No.2 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	13.5%	B
		B			B
No.1 C.W.R.S.	13.5%	B	No.2 C.W.R.S.	13.5%	B
No.3 C.W.R.S.		C	No.2 C.W.R.S.	12.5%	C
No.2 C.W.R.S.	12.5%	D	No.1 C.W.R.S.	12.5%	C
		D			
No.1 C.W.R.S.	12.5%	D	No.3 C.W.R.S.		D

Ash Content, %

No.3 C.W.R.S.		A		
No.2 C.W.R.S.	13.5%	B		
		B		
No.2 C.W.R.S.	12.5%	B	C	
		B	C	
No.1 C.W.R.S.	12.5%	B	C	
		B	C	
No.1 C.W.R.S.	14.5%	B	C	
			C	
No.1 C.W.R.S.	13.5%		C	

No.3 C.W.R.S.		A	
No.2 C.W.R.S.	13.5%	B	
		B	
No.2 C.W.R.S.	12.5%	B	
		B	
No.1 C.W.R.S.	12.5%	B	C
		B	C
No.1 C.W.R.S.	14.5%	B	C
			C
No.1 C.W.R.S.	13.5%		C

Color, units

No.3 C.W.R.S.		A		
No.2 C.W.R.S.	13.5%	B		
No.2 C.W.R.S.	12.5%	C		
		C		
No.1 C.W.R.S.	14.5%	C	D	
			D	
No.1 C.W.R.S.	13.5%		D	E
				E
No.1 C.W.R.S.	12.5%			E

No.3 C.W.R.S.		A
No.1 C.W.R.S.	14.5%	B
		B
No.2 C.W.R.S.	12.5%	B
		B
No.2 C.W.R.S.	13.5%	B
No.1 C.W.R.S.	13.5%	C
		C
No.1 C.W.R.S.	12.5%	C

Starch Damage, Farrand units

No.3 C.W.R.S.		A		
		A		
No.1 C.W.R.S.	12.5%	A		
		A		
No.2 C.W.R.S.	12.5%	A	B	
			B	
No.1 C.W.R.S.	13.5%		B	C
			B	C
No.1 C.W.R.S.	14.5%		B	C
				C
No.2 C.W.R.S.	13.5%			C

No.3 C.W.R.S.		A	
No.1 C.W.R.S.	12.5%	B	
		B	
No.2 C.W.R.S.	12.5%	B	
		B	
No.2 C.W.R.S.	13.5%	B	C
			C
No.1 C.W.R.S.	14.5%		C
			C
No.1 C.W.R.S.	13.5%		C

Alpha-amylase Activity, units/g

No.3 C.W.R.S.	A		No.3 C.W.R.S.	A	
No.2 C.W.R.S. 13.5%	B		No.2 C.W.R.S. 13.5%	B	
	B			B	
No.2 C.W.R.S. 12.5%	B		No.2 C.W.R.S. 12.5%	B	
	B			B	
No.1 C.W.R.S. 12.5%	B	C	No.1 C.W.R.S. 12.5%	B	
		C		B	
No.1 C.W.R.S. 13.5%		C	No.1 C.W.R.S. 13.5%	B	
		C		B	
No.1 C.W.R.S. 14.5%		C	No.1 C.W.R.S. 14.5%	B	

Amylograph Peak Viscosity, B.U.

No.1 C.W.R.S. 14.5%	A		No.1 C.W.R.S. 14.5%	A	
	A			A	
No.1 C.W.R.S. 13.5%	A	B	No.1 C.W.R.S. 13.5%	A	B
		B			B
No.1 C.W.R.S. 12.5%		B	No.1 C.W.R.S. 12.5%		B
No.2 C.W.R.S. 13.5%		C	No.2 C.W.R.S. 13.5%	C	
		C		C	
No.2 C.W.R.S. 12.5%		C	No.2 C.W.R.S. 12.5%	C	
No.3 C.W.R.S.		D	No.3 C.W.R.S.	D	

Baking Absorption

No.1 C.W.R.S. 14.5%	A		No.1 C.W.R.S. 14.5%	A	
No.2 C.W.R.S. 13.5%	B		No.1 C.W.R.S. 13.5%	B	
	B			B	
No.3 C.W.R.S.	B		No.2 C.W.R.S. 13.5%	B	
	B			B	
No.1 C.W.R.S. 13.5%	B		No.3 C.W.R.S.	B	C
					C
No.2 C.W.R.S. 12.5%	C		No.2 C.W.R.S. 12.5%		C
	C				C
No.1 C.W.R.S. 12.5%	C		No.1 C.W.R.S. 12.5%		C

Gassing Power

No.3 C.W.R.S.		A	No.3 C.W.R.S.		A
No.2 C.W.R.S.	12.5%	B	No.2 C.W.R.S.	12.5%	B
		B			
No.2 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	12.5%	C
					C
No.1 C.W.R.S.	12.5%	C	No.2 C.W.R.S.	13.5%	C
No.1 C.W.R.S.	13.5%	D	No.1 C.W.R.S.	13.5%	D
					D
No.1 C.W.R.S.	14.5%	E	No.1 C.W.R.S.	14.5%	D

Bread

Loaf Volume, cm

No.1 C.W.R.S.	14.5%	A	No.1 C.W.R.S.	14.5%	A
No.2 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	13.5%	B
					B
No.1 C.W.R.S.	13.5%	C	No.2 C.W.R.S.	13.5%	B
No.3 C.W.R.S.		D	No.2 C.W.R.S.	12.5%	C
					C
No.2 C.W.R.S.	12.5%	E	No.1 C.W.R.S.	12.5%	C
		E			
No.1 C.W.R.S.	12.5%	E	No.3 C.W.R.S.		D

Appearance

No.1 C.W.R.S.	14.5%	A	No.1 C.W.R.S.	14.5%	A	
No.2 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	13.5%	B	
		B			B	
No.1 C.W.R.S.	13.5%	B	No.2 C.W.R.S.	13.5%	B	C
						C
No.2 C.W.R.S.	12.5%	C	No.1 C.W.R.S.	12.5%		C
		C				C
No.1 C.W.R.S.	12.5%	C	No.2 C.W.R.S.	12.5%		C
		C				
No.3 C.W.R.S.		C	No.3 C.W.R.S.		D	

Crumb Color

No.1 C.W.R.S.	14.5%	A	No.1 C.W.R.S.	14.5%	A
No.2 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	13.5%	B
		B			B
No.1 C.W.R.S.	13.5%	B	No.2 C.W.R.S.	13.5%	B
No.2 C.W.R.S.	12.5%	C	No.2 C.W.R.S.	12.5%	C
					C
No.1 C.W.R.S.	12.5%	D	No.1 C.W.R.S.	12.5%	C
No.3 C.W.R.S.		E	No.3 C.W.R.S.		D

Crumb Texture

No.1 C.W.R.S.	14.5%	A		No.1 C.W.R.S.	14.5%	A
		A				A
No.2 C.W.R.S.	13.5%	A	B	No.1 C.W.R.S.	13.5%	A
		A	B			A
No.1 C.W.R.S.	13.5%	A	B	No.1 C.W.R.S.	12.5%	A
		A	B			A
No.1 C.W.R.S.	12.5%	A	B	No.2 C.W.R.S.	12.5%	A
		A	B			A
No.2 C.W.R.S.	12.5%	A	B	No.2 C.W.R.S.	13.5%	A
			B			
No.3 C.W.R.S.			B	No.3 C.W.R.S.		B

Blend Loaf Volume, cm

No.1 C.W.R.S.	14.5%	A	No.1 C.W.R.S.	14.5%	A
No.2 C.W.R.S.	13.5%	B	No.1 C.W.R.S.	13.5%	B
		B			B
No.1 C.W.R.S.	13.5%	B	No.2 C.W.R.S.	13.5%	B
No.3 C.W.R.S.		C	No.2 C.W.R.S.	12.5%	C
		C			C
No.1 C.W.R.S.	12.5%	C	No.1 C.W.R.S.	12.5%	C
		C			
No.2 C.W.R.S.	12.5%	C	No.3 C.W.R.S.		D

Farinogram

Absorption

No.3 C.W.R.S.		A		
		A		
No.1 C.W.R.S.	14.5%	A	B	
		A	B	
No.2 C.W.R.S.	13.5%	A	B	C
			B	C
No.1 C.W.R.S.	13.5%		B	C
			B	C
No.2 C.W.R.S.	12.5%		B	C
				C
No.1 C.W.R.S.	12.5%			C

No.3 C.W.R.S.		A	
		A	
No.1 C.W.R.S.	14.5%	A	B
		A	B
No.2 C.W.R.S.	12.5%	A	B
		A	B
No.2 C.W.R.S.	13.5%	A	B
		A	B
No.1 C.W.R.S.	13.5%	A	B
			B
No.1 C.W.R.S.	12.5%		B

Development Time

No.1 C.W.R.S.	14.5%	A
No.2 C.W.R.S.	13.5%	B
		B
No.1 C.W.R.S.	13.5%	B
No.2 C.W.R.S.	12.5%	C
		C
No.1 C.W.R.S.	12.5%	C
		C
No.3 C.W.R.S.		C

No.1 C.W.R.S.	14.5%	A	
		A	
No.1 C.W.R.S.	13.5%	A	B
			B
No.2 C.W.R.S.	13.5%	C	B
		C	
No.1 C.W.R.S.	12.5%	C	D
			D
No.2 C.W.R.S.	12.5%		D
No.3 C.W.R.S.		E	

Extensigram

Length

No.1 C.W.R.S.	14.5%	A			
		A			
No.2 C.W.R.S.	13.5%	A	B		
			B		
No.1 C.W.R.S.	13.5%		B	C	
				C	
No.2 C.W.R.S.	12.5%			C	D
					D
No.3 C.W.R.S.					D
					D
No.1 C.W.R.S.	12.5%				D

No.1 C.W.R.S.	14.5%	A	
		A	
No.2 C.W.R.S.	13.5%	A	B
			B
No.1 C.W.R.S.	13.5%	C	B
		C	
No.2 C.W.R.S.	12.5%	C	D
			D
No.1 C.W.R.S.	12.5%	E	D
		E	
No.3 C.W.R.S.		E	

Height at 5 cm, B.U.

No.1 C.W.R.S.	12.5%	A	
		A	
No.1 C.W.R.S.	13.5%	A	B
		A	B
No.2 C.W.R.S.	12.5%	A	B
		A	B
No.3 C.W.R.S.		A	B
		A	B
No.1 C.W.R.S.	14.5%	A	B
			B
No.2 C.W.R.S.	13.5%		B

No.1 C.W.R.S.	13.5%	A
		A
No.1 C.W.R.S.	12.5%	A
No.2 C.W.R.S.	13.5%	B
		B
No.1 C.W.R.S.	14.5%	B
		B
No.2 C.W.R.S.	12.5%	B
		B
No.3 C.W.R.S.		B

Maximum Height, B.U.

No.1 C.W.R.S.	14.5%	A		
		A		
No.1 C.W.R.S.	13.5%	A		
		A		
No.1 C.W.R.S.	12.5%	A	B	
			B	
No.2 C.W.R.S.	13.5%		B	C
				C
No.3 C.W.R.S.				C
				C
No.2 C.W.R.S.	12.5%			C

No.1 C.W.R.S.	13.5%	A	
		A	
No.1 C.W.R.S.	12.5%	A	B
			B
No.1 C.W.R.S.	14.5%		B
			B
No.2 C.W.R.S.	13.5%	C	B
		C	
No.2 C.W.R.S.	12.5%	C	
No.3 C.W.R.S.		D	

Area, cm

No.1 C.W.R.S.	14.5%	A			
		A			
No.1 C.W.R.S.	13.5%	A	B		
			B		
No.2 C.W.R.S.	13.5%		B	C	
				C	
No.1 C.W.R.S.	12.5%			C	D
					D
No.3 C.W.R.S.					D
					D
No.2 C.W.R.S.	12.5%				D

No.1 C.W.R.S.	13.5%	A	
		A	
No.1 C.W.R.S.	14.5%	A	B
			B
No.2 C.W.R.S.	13.5%		B
			B
No.1 C.W.R.S.	12.5%		B
No.2 C.W.R.S.	12.5%	C	
No.3 C.W.R.S.		D	

Alveogram

Length, cm

No.1	C.W.R.S.	14.5%	A
No.2	C.W.R.S.	13.5%	B
			B
No.1	C.W.R.S.	13.5%	B
No.3	C.W.R.S.		C
			C
No.1	C.W.R.S.	12.5%	C
			C
No.2	C.W.R.S.	12.5%	C

No.1	C.W.R.S.	14.5%	A
No.2	C.W.R.S.	13.5%	B
			B
No.1	C.W.R.S.	13.5%	B
No.2	C.W.R.S.	12.5%	C
			C
No.1	C.W.R.S.	12.5%	C
No.3	C.W.R.S.		D

P(height x 1.1), mm

No.2	C.W.R.S.	12.5%	A	
			A	
No.1	C.W.R.S.	12.5%	A	
			A	
No.3	C.W.R.S.		A	
No.1	C.W.R.S.	13.5%	B	
			B	
No.2	C.W.R.S.	13.5%	B	C
				C
No.1	C.W.R.S.	14.5%		C

No.3	C.W.R.S.		A	
			A	
No.1	C.W.R.S.	12.5%	A	B
			A	B
No.2	C.W.R.S.	12.5%	A	B
				B
No.1	C.W.R.S.	13.5%		B
				B
No.2	C.W.R.S.	13.5%	C	B
			C	
No.1	C.W.R.S.	14.5%	C	

Area, cm

No.1	C.W.R.S.	14.5%	A
			A
No.1	C.W.R.S.	13.5%	A
			A
No.2	C.W.R.S.	13.5%	A
			A
No.1	C.W.R.S.	12.5%	A
			A
No.3	C.W.R.S.		A
			A
No.2	C.W.R.S.	12.5%	A

No.1	C.W.R.S.	13.5%	A	
			A	
No.2	C.W.R.S.	13.5%	A	B
			A	B
No.1	C.W.R.S.	14.5%	A	B
			A	B
No.1	C.W.R.S.	12.5%	A	B
				B
No.2	C.W.R.S.	12.5%	C	B
			C	
No.3	C.W.R.S.		C	

W. x ergs

No.1 C.W.R.S.	14.5%	A		
		A		
No.1 C.W.R.S.	13.5%	A	B	
		A	B	
No.3 C.W.R.S.		A	B	
		A	B	
No.1 C.W.R.S.	12.5%	A	B	
			B	
No.2 C.W.R.S.	13.5%		B	
			B	
No.2 C.W.R.S.	12.5%		B	

No.1 C.W.R.S.	13.5%	A		
		A		
No.1 C.W.R.S.	14.5%	A		
		A		
No.2 C.W.R.S.	13.5%	A	B	
		A	B	
No.1 C.W.R.S.	12.5%	A	B	C
			B	C
No.2 C.W.R.S.	12.5%		B	C
				C
No.3 C.W.R.S.				C

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