

STUDY OF SOME FACTORS AFFECTING  
PELSHENKE TEST FOR BREADMAKING  
QUALITY

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Francisco Javier Rodriguez-Bores

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A dissertation submitted to the Faculty of Graduate Studies of  
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## Carolina

Hay en ti fragancia e ímpetu juvenil, emoción palpitante y sostenida que da una impresión de abundancia y prodigalidad. Me has contagiado de un sentimiento expectante de superación que sin ti no hubiera sido posible obtener la culminación de mis estudios. A ti, mas que a nadie, dedico esta tesis porque tu eres el ser que ha llenado mi vida de dulcísimas y gratas emociones, porque con tu dinamismo y cariño me has alentado en los momentos mas difíciles haciendo de mis ensueños realidades. Con todo mi amor.

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## ABSTRACT

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Study of Some Factors Affecting Pelshenke Test for Breadmaking Quality

Major Professor: Dr. Walter Bushuk.

The Pelshenke Test is used in Australia, Europe, Africa and Mexico for screening wheat lines for breadmaking quality in breeding programs. The present study indicated that mixing procedures similar to those used in baking tests gives higher precision than manual mixing used in the classical Pelshenke Test. The effects of mixing time and speed on Pelshenke value were determined. Pelshenke value increased directly with mixing time but mixing speed had no effect. The Test has been applied to rye and triticale to examine the feasibility of using it for screening breeding lines of these cereals in addition to wheat.

The Pelshenke value is affected by environment (location and growth) as well as by cultivar. The location differences were generally smaller than the cultivar differences. The usefulness of the Pelshenke Test as an index of breadmaking quality was further examined by determining its relationship to other quality tests such as the Zeleny Sedimentation value and farinograph measurements. In general, highly significant correlations were obtained.

The effect of environment on the Pelshenke value is mainly through its effect on protein content and protein solubility. Of the protein fractions, glutenin seems to play an important role in the Pelshenke Test. Variations in amino acid composition in flours of widely different protein content was consistent with the protein solubility results.

Effects of major flour constituents such as protein content, the

amount of starch damage, pentosans, lipids and enzymes on the Pelshenke value were investigated. Pelshenke value increased directly with all the constituents except for enzymes. The effects of commonly used flour improvers and one sulfhydryl blocking agent (N-ethylmaleimide) were also examined. Additions of potassium bromated and ascorbic acid produced an increase in Pelshenke value to an optimum followed by a decrease with further additions. Cysteine had a negative effect on Pelshenke value. N-ethylmaleimide also had a negative effect because of its ability to inhibit yeast activity.

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## LIST OF ABBREVIATIONS

ABS	.....	BAKING ABSORPTION, %
ALV	.....	AACC LOAF VOLUME, cc
DIA	.....	DIASTATIC ACTIVITY, M.u. (Maltose Units)
FAB	.....	FARINOGRAPH ABSORPTION, %
FDT	.....	FARINOGRAPH DEVELOPMENT TIME, min
FLA	.....	FLOUR ASH, %
FLP	.....	FLOUR PROTEIN, %
FLY	.....	FLOUR YIELD, %
GAP	.....	GASSING POWER, mmHg
GRT	.....	GRINDING TIME, min
MDT	.....	MIXOGRAPH DEVELOPMENT TIME, min
MTI	.....	MIXING TOLERANCE INDEX, min
NIF	.....	NITROGEN FERTILIZER, lb/ac
PEL	.....	PELSHENKE VALUE, min
PEF	.....	PELSHENKE VALUE IN FLOUR, min
RLV	.....	REMIX LOAF VOLUME, cc
SED	.....	ZELNY SEDIMENTATION VALUE, cc
STD	.....	STARCH DAMAGE, F.u. (Farrand Units)
WHP	.....	WHEAT PROTEIN, %

## I. INTRODUCTION

Wheat is the most important staple food crop of the world. It provides approximately 20% of the calories consumed by the world's population. It is grown on a larger area and produces more grain than any other cereal. The cultivation of wheat extends from very Southern regions of Australia and South America to a latitude of about 60° north in Asia, Europe and North America. Wheat is grown over a wide range of elevations from sea level to over 3,000 meters in Ecuador and Kenya. There are many factors that affect wheat production; all of them must be considered together if the contribution of wheat to the world food supply is to be significantly increased through agricultural research.

By far the most important segment of agricultural research relative to food production has been the breeding of higher yielding, better quality varieties of cereal grains, in general, and wheat in particular. The introduction of the semi-dwarf wheat varieties, developed in Mexico, into India and Pakistan has led to the so-called Green Revolution. Within a period of five years, from 1967 to 1972, India increased its wheat production by almost 100%; most of this increase can be directly attributed to the size of the new high-yielding varieties.

In order to be a viable commercial variety (cultivar), a new strain of wheat must offer some advantages in agronomic and/or end-use qualities. Since most of the wheat grown around the world is used for the production of bread, the new variety, developed by the breeder, must have a certain minimum level of breadmaking quality. The actual level of quality varies quite widely among countries that have wheat breeding programs depending, to a large extent, on the class of wheat that can be grown in a specific country or area. The lack of suitable screening tests for breadmaking

quality of lines in wheat breeding programs, presently constitutes one of the problems in agricultural research that requires urgent solution.

A suitable quality screening test should be simple and rapid so that it can be used to examine a large number of lines to facilitate the discarding of undesirable lines and thereby improve the efficiency of the breeding program. The test should also give a reasonably accurate measure of quality so that lines with satisfactory quality are not inadvertently discarded.

In the past 50 years, cereal chemists have developed numerous tests for predicting the breadmaking quality of wheat. Among the tests that have been developed, the so-called Pelshenke Test has been applied quite successfully in Latin America, Africa, Australia and Europe for screening new wheat varieties because it measures a very important parameter of baking quality, namely the dough strength. In North America the Pelshenke Test is used to some extent and is commonly known as the Wheat Meal Fermentation Time Test.

Since the wheat kernel comprised many different constituents, it can be stated that breadmaking quality of wheat depends on the relative proportion of individual constituents in the flour, on the properties of these constituents and on the processing used to convert the wheat into bread. The aim of the work presented in this thesis was to study the contribution of some of these constituents to the Pelshenke Test time relative to its ability to predict breadmaking quality. In addition, a number of other technologically relevant factors such as variety, growth environment, meal (or flour) particle size, dough mixing time and chemical ingredients (used in the baking industry) were investigated. Results of these ancillary investigations will be presented and discussed.

## II. LITERATURE REVIEW

### A. Introduction

There are many approaches that can be taken to reviewing the literature that is relevant to this thesis project. If the review is restricted to the literature that specifically mentions the Pelshenke Test, then the review would be too brief and too narrow because of the extremely small number of documented studies on this topic. In the other extreme, if a broad approach is adopted to cover all aspects of the nature and inheritance of quality in wheat, the review would be too long and unwieldy. Obviously an intermediate approach had to be chosen.

The review that follows will be presented in three major subsections. The first will review the literature on those wheat constituents that are known to be important to its end-use quality. This subsection will include references to genetic, environmental and processing factors if they are considered relevant to the quality contribution of the constituents in question. The second subsection will deal with the literature on the need, application, and value of quality tests for screening lines of wheat in breeding programs. The final section will review the literature on the Pelshenke Test. Finally, the review will deal only with bread wheats. References to durum (macaroni) and soft (biscuit) wheats will be made only if they are explicitly relevant to the subject of the thesis. It should be noted that the division between bread and biscuit wheat is not a sharp one; there is considerable overlap. A low-protein bread wheat in some countries may be a high-protein biscuit wheat in others.

One further qualification. The term "quality", as used in this review and indeed throughout the thesis, refers to milling and baking quality for the production of North American-type white bread. It is

synonymous with "breadmaking quality". "Nutritional quality", which is particularly important in countries where wheat products provide most of the protein for human nutrition, is compatible with breadmaking quality insofar as it relates to the protein "content" of the wheat (Shukla, 1975). The two qualities are incompatible in terms of the first limiting essential amino acid, lysine. Wheat protein of higher lysine content is usually lower in specific breadmaking quality (Middleton et al., 1954; Mattern et al., 1970). Nutritional quality is outside the subject of this thesis and will not be discussed further.

#### B. Wheat Constituents Related to Quality

The wheat kernel comprises three major morphological parts (Bradbury et al., 1956); 83% endosperm, 14.5% bran, and 2.5% embryo or germ. In milling, the bran and the embryo are separated from the endosperm which is then ground into flour. Accordingly, insofar as quality is concerned, it is sufficient to consider only the constituents of the endosperm. Contamination of the flour by bran and embryo components is an indication of inefficient milling and is generally detrimental to quality (Eva and Fisher, 1957).

The main constituents of wheat endosperm are: carbohydrates (starch and pentosans) (70.4%), protein (13.2%), water (14%), lipids (1.3%) (Bushuk, 1975). The figures in parenthesis are average values for Canadian hard red spring wheat expressed on as is basis. Relevant literature on each major constituent will be reviewed in separate subsections.

##### 1. Starch

Starch is the commonest food reserve material of the plant kingdom. It forms the major component of the wheat kernel and, hence of the flour

prepared from it. Starch is normally present in the form of characteristic birefringent granules. Starch granules from different plants vary distinctly in size and shape. The granules, which are insoluble in cold water, swell reversibly when suspended in water. As the temperature of the aqueous suspension is increased the swelling process proceeds until the granules burst with the formation of starch pastes (MacMasters et al., 1975). This swelling and eventual disruption of the starch granules is commonly called gelatinization. The most easily observed change in the process of gelatinization is the rapid and complete loss of birefringence of individual granules when viewed microscopically with plane polarized light (Zobel and Senti, 1959; Wivinis and Maywald, 1967). All granules in a starch sample do not lose birefringence at the same temperature or at the same rate; gelatinization takes place over a range of temperature which is characteristic of the particular starch granules (Aspinall, 1970).

The granule of starch comprises a mixture of two polysaccharide components: amylose, which consists of glucose units connected to each other by the alpha-1,4-glycosidic linkage resulting a linear chain of glucose units, and amylopectin which has a highly branched structure in which the glucose units are connected by alpha-1,4-bonds in the main chains and by alpha-1,6-bonds at the branch points.

When wheat is milled into flour, a portion of the wheat starch granules undergoes physical damage as a consequence of the grinding action of the mill rolls. Jones (1940) found that the amount of damaged starch produced varied according to the conditions of milling. The starches of different classes of wheat differ in susceptibility to physical damage, i.e. hard wheat flours usually have much higher starch damage values than

soft wheat flours (Williams, 1967). Damaged starch absorbs 2.5 times more water than granular starch (Greer and Stewart, 1959). Also, it is more susceptible to starch-degrading enzymes (Tipples et al., 1966). Starch damage and amylase activity are extremely important in determining the baking absorption of a flour (Tipples et al., 1966). Damaged starch acts like a sponge in the presence of water and so offers a potential way of increasing water absorption of a flour and hence bread yield (Tipples, 1975). Accordingly, an increase in the damaged starch level of a flour leads to a direct increase in the absorption of water by the flour at the mixing stage. Differences in water absorption of flours from hard and soft English wheats can be accounted for largely by the variations in protein and damaged-starch contents of the flours (Greer and Stewart, 1959). A failure of some flours to show the increase in water-absorption expected from the increase in damaged-starch content has been attributed to unusually high amylase activities. The rapid hydrolysis of the damaged starch and undue softening of the dough during fermentation must be counteracted by decreasing absorption (Jones, 1940). A certain minimum level of damaged starch is desirable and necessary to provide fermentable sugars by the actions of amylases (to be reviewed later), to maintain dough gas-producing power during fermentation and proofing (Jones, 1940). If damaged starch is increased above a certain maximum value characteristic for the baking procedure used, bread quality will suffer (Kulp, 1972).

According to Sandstedt (1961), starch in a bread dough has the following functions: a) it dilutes the gluten to a desired consistency, b) it furnishes fermentable sugars through amylase action, c) it provides a surface suitable for a strong interaction with the gluten, d) it becomes flexible during partial gelatinization, thereby permitting the stretching

of the granules to form gas-cell membranes in the bread crumb, and e) it takes up some of the water from the gluten which loses its water binding capacity because of the thermal denaturation in the baking phase. During baking, it is mainly the gluten films that become rigid and form the three-dimensional structure of a loaf of bread.

Recent fractionation and reconstitution studies by Hoseney et al. (1971) have shown that, contrary to previous claims, wheat starch is not unique in its contribution to breadmaking. They found that barley and rye starches were as functional as wheat starch in breadmaking. The similarity in the contributions of those starches to the functional properties in baking seemed to be related to the physical characteristics of their granules. As far as the author is aware, the effect of starch damage on Pelshenke Test has not been investigated.

## 2. Proteins

The word protein was derived from the Greek "proteios" meaning primary. Proteins are the most important organic molecules found in all living cells. Chemically, proteins are polymers of about 20 different amino acids linked together by peptide bonds to form giant complex molecules. There are many different kinds of proteins, each synthesized for a specific biological function; it may serve as an enzyme catalyzing a specific chemical reaction, serve as a structural or storage substance, bind and transport ions, or carry out some other function (e.g. hormones).

Protein Content and Quality in Wheat. The protein content of wheat or flour can be determined rapidly and accurately by the Kjeldahl method for nitrogen (AACC, 1969). The nitrogen content is converted to protein content by multiplying by a constant factor(5.7). This factor was originally determined from the nitrogen content of gluten which was considered,

erroneously, to be a pure protein. The factor determined from the total amino acid composition is very close to the classical 5.7 (Tkachuk, 1966).

The protein content of wheat depends primarily on two factors: variety and environment. In Canada, the genetic factor is controlled to some extent by the statute-controlled licencing of cultivars that can be grown commercially. The success of this method of control is perhaps best demonstrated by the fact that spring wheats released for the bread class have continued to maintain the high protein content of Canada's most famous hard red spring wheat variety, Marquis.

The effect of environment on the agronomic and quality characteristics, especially protein content, has been investigated by several workers. Miller et al. (1950) and Gunthar and McGinnis (1957) observed that the protein content in wheat could be modified by breeding and selection and also by applying fertilizers. However, there are considerable problems in combining high yielding capacity with satisfactory baking quality because of the negative correlation usually found between grain protein content and grain yield (Haunold et al., 1962; Baker et al., 1968). It has been difficult to achieve the combination of high yield, high protein content and good breadmaking quality by plant breeding. Nevertheless, Johnson et al. (1975) working with a cross between Atlas 66, a high protein soft wheat with poor breadmaking quality, and Comanche, a bread wheat with good breadmaking quality, demonstrated that the high protein line selected had entirely satisfactory milling and baking properties. Accordingly, it should be possible to improve both yield and protein content and maintain baking quality by breeding.

It is well documented that the physical and chemical properties of wheat grain as well as protein quality under normal growing conditions

are almost entirely an inherited characteristic. Protein quantity in wheat depends primarily on soil and climatic conditions during the growing period (Wahhab and Hussain, 1957; Fernandez and Laird, 1959). The production of high protein wheat with satisfactory breadmaking quality, by the application of nitrogen fertilizer, has been observed by several workers (Fisher and Jones, 1931; Worzella, 1944; Long and Sherbakoff, 1951; Sibbit and Bauer, 1970). Wahhab and Hussain (1957) reported that the application of fertilizers increased the protein content of wheat grain, however, Fernandez and Laird (1959) observed that the application of 45 lbs of nitrogen per acre decreased the protein content of the whole grain, while larger applications increased it. Despite its profound effect on protein content, the environment had no effect on the electrophoresis of the gliadin proteins of wheat (Lee and Ronalds, 1967). This suggests that qualitatively the protein remains essentially the same while the protein content of the grain varies quite widely.

Considerable attention has been given to the amino acid composition of wheat varieties or commercial blends of various origins. Published reports (Renner et al., 1953; Gunthard and McGinnis, 1957) show that environmental factors, including soil type, fertilizer, and climate have no effect on amino acid composition of normally developed grain.

**Protein Quality for Breadmaking.** Proteins of wheat have received considerable attention in relation to their contribution to the breadmaking quality of flour. Breadmaking properties of wheat flour depend on numerous factors, including wheat variety, environmental conditions during growth, soil fertility, the milling process, and the chemical composition of the flour. The effect of many of these variables is indirect. It is the resulting variation in chemical composition, especially of flour

protein, that causes variation in breadmaking quality. Relevant literature on qualitative differences in the proteins of wheat cultivars is reviewed in the following five subsections.

**Protein Solubility Fractionation.** One of the earliest tests of protein quality for breadmaking was based on the determination of the amount and the viscoelasticity (rubber-like property) of the gluten obtained from the flour. The first recorded attempt of isolation of flour proteins was that of Beccari, who in 1728 achieved a separation of a substance from dough which he named "gluten" (from the Greek meaning sticky). This he did by washing the starch from a dough under a stream of water, leaving a yellowish sticky mass as residue (Gortner, 1942).

Approximately 75 years after the discovery of Beccari, Einhof (1805) extracted from the crude gluten a substance which was soluble in 70% ethanol, and which could be precipitated on dilution of the alcoholic solution with water. This partially purified substance was even more sticky than gluten itself, and he named it "gliadin" (from the Greek word meaning glue). The remaining insoluble protein was partially purified by Taddei in 1820 who named this fraction "glutenin". This substance was unlike gliadin, being much firmer and not sticky (Gortner, 1942).

Modern cereal chemistry began with the classical work of Osborne (1907), in which he described fractionation procedures for flour proteins which are the basis of the methods used today. He defined four protein fractions and attempted to determine the amino acid composition of each of the protein fractions. Osborne (1907) classified wheat proteins as follows: albumins were the water-soluble proteins, globulins were soluble in salt solutions, gliadins dissolved in 70% aqueous ethanol, and glutenins dissolved in dilute acid or base. With minor modifications, the solubility

fractionation method of Osborne has been used extensively in studies of the structure and function of wheat proteins (Tanaka and Bushuk, 1972; Orth and Bushuk, 1973).

**Soluble Proteins.** Approximately 10 to 15% of the total protein in wheat consists of albumins and globulins (Doby, 1965; Whitehouse, 1973). These two groups of proteins are generally referred to as the soluble proteins. Most of the enzymes in flour are extracted with this group of proteins. The role of albumins and globulins that are not enzymes in the cereal seed is not clearly understood. There has been considerable disagreement on the influence of the albumins and globulins on breadmaking quality (Pence et al., 1954; Mattern and Sandstedt, 1957). Recent studies suggest that the albumin and globulin proteins contribute very little to the breadmaking quality of flours from normally developed wheat (Pence, 1962; Hoseney et al., 1969).

The albumin and globulin proteins usually have a better balanced amino acid composition than gliadins and glutenins in relation to human and animal nutrition. This advantage is nullified when considered on overall grain composition with respect to amino acids because of the much higher content of gliadins and glutenins. The gliadins, in particular, are a very poor source of lysine, tryptophan and sulphur containing amino acids (Shukla, 1975).

**Insoluble or Gluten Proteins.** Gluten is the protein complex that gives dough its elastic, plastic, and cohesive properties (Barmore, 1947). It is mainly proteinaceous in nature but contains substantial quantities of lipid and carbohydrate materials. The two major proteins in gluten are the gliadins and glutenins. It has been shown that while glutenin is a multichain complex stabilized by disulfide bonds, gliadins are compact,