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# SCREENING OF BREAD WHEATS FOR MILLING AND BAKING QUALITY IN CANADA

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## ABSTRACT

Selection for milling and baking qualities of wheat varieties of the Canadian hard red spring class in breeding programmes begins at the fourth generation. At this stage, screening tests include grinding time for grain hardness, wheat falling number for susceptibility to sprouting, flour yield on Brabender Quadrumat Junior Mill, flour protein content, and micromixograph test on 10 g of flour. Retention of varieties is based on the comparative quality index calculated from flour yield, protein content, and mixograph dough development time. The second stage of screening is based on a larger number of tests including as many as eight different baking tests. Rejection is based on deficiencies compared to data for primary and secondary standard varieties grown with the experimental varieties. The final phase of screening for quality is the so-called cooperative (C) test. Three different laboratories are involved in generating the quality data for the C test samples. Decision on rejection of varieties is made by the national Expert Committee on Grain Quality. The tests used for screening are modified from time to time to reflect changes in milling and baking technology of domestic and export markets. The final stage of the variety development programme covers licensing, purification, increase of seed, and distribution of seed to the farmers. The time required for the complete development cycle, from the first cross to licensing, is about 11 years.

## KEYWORDS

Hard red spring wheat, bread wheat, Canadian wheat, breeding, screening for quality, milling quality, baking quality.

## INTRODUCTION

Scientific wheat breeding in Canada began at the turn of the twentieth century. In 1909, seed of Canada's most famous wheat variety, Marquis, developed by Dr Charles Saunders, was distributed to farmers. It combined the high yielding potential and bread-making quality of Red Fife with early maturity derived from an unknown variety of hard red wheat from Calcutta. Marquis quickly replaced Red Fife as the predominant bread wheat variety on the Canadian Prairies and retained that position until it was superceded by Thatcher in the 1940's. In 1925, Marquis was designated the legal standard of quality for Canadian hard red spring (CWRS) class of wheat in the statutory grading specifications and has retained that designation. Many advances have been made in breeding methods and testing for agronomic performance and quality. Today, variety development in Canada is carried on at about 15 institutions, most belonging to the Federal Government supplemented with some from Universities and private companies.

A new Canadian wheat variety must meet a number of legal requirements. Firstly, it must conform to the regulations of the Seeds Act in relation to purity, uniformity, and distinguishability. Secondly, it must meet the grading specifications described in the Canada Grain Act. This act specifies that to qualify for the top two grades of the CWRS class of wheat, the new variety must be 'equal to Marquis'. It is generally interpreted that this specification applies to all characteristics, including milling and baking quality. Because our grading system is based on visual distinguishability of wheat classes, varieties offered for the CWRS class must be visually distinguishable from varieties of other classes such as Canada Western Red Winter and Canada Utility. This requirement is unique to the Canadian system. Furthermore, our statutory wheat grading regulations require that the grain of a new variety be uniform in kernel size, shape, and colour and have consistently good test weight. Accordingly, our system of screening breeding lines for milling and baking quality has developed over the years to meet the statutory requirements, and to keep up with the changing milling and baking technologies of wheat consumers at home and abroad.

## TESTING FOR QUALITY

The Canadian process of developing new wheat varieties can be described in three relatively distinct, albeit arbitrary, stages. First is the initial crossing and early selection stage. In this stage, which may require up to 10 generations, the breeder attempts to select plants that have the desired combination of traits and are uniform and stable. The key to eventual success depends on the choice of the parents; regular use is made of the available

**Table 1. A typical course of a wheat hybrid population in the generation following the cross.**

| Year | Generation | Location | Type of plot | Traits selected |
|---|---|---|---|---|
| 1986 | Cross made in growth cabinet at Winnipeg | | | |
| | $F_1$ | Winnipeg | Spaced plants | None |
| 1987 | $F_2$ | Winnipeg | Spaced plants | LR, HD, SR, M, D |
| | $F_3$ | Greenhouse | Head rows | K |
| 1988 | $F_4$ | Winnipeg | Head rows | LR, HD, SR, Ht, M, L, G, K, QS |
| | $F_5$ | Greenhouse | Head rows | K |
| 1989 | $F_6$ | Winnipeg | Head rows | LR, HD, SR, Ht, M, L, G, K, QS |
| | $F_7$ | New Zealand | Head rows | H, L., Sh |
| 1990 | | Winnipeg | Small increase | LR, HD, SR, H, M, L, Sh, Ht, D, TW, K, QS |
| 1991 | | Manitoba and eastern Sask. | Yield test A at 5 locations | LR, HD, SR, RR, LS, Bu, M, L, Sh, Y, D, TW, K, Q1 |
| 1992 | | Manitoba and eastern Sask. | Yield test B at 7 locations | LR, HD, SR, RR, LS, Bu, M, L, Sh, Y, D, TW, K, Q2, Q3 |
| 1993 | | Manitoba and eastern Sask. | Yield test C at 10 locations | LR, HD, SR, RR, LS, Bu, M, L, Sh, Y, D, TW, K, Q4 |
| 1994 | | Manitoba and eastern Sask. (Plus 8 western locations) | Yield test C | LR, HD, SR, RR, LS, Bu, Sa, M, L, Sh, Y, D, TW, K, Q4, Q5 |
| 1995 | | Prairies | Yield test C at 18 locations | LR, HD, SR, RR, LS, Bu, Sa, M, L, Sh, Y, D, TW, K, Q4, Q5 |
| 1996 | Support for licensing obtained in February, followed by increase of seed at Indian Head and distribution of seed through winter of 1996/97. | | | |

Abbreviations

| | | | |
|---|---|---|---|
| Bu | Bunt resistance | QS | Quality screening (60 g [wheat]) |
| D | Dormancy | Q1 | Milling & Baking (1 kg) |
| $F_X$ | Filial generation | Q2 | M & B composite (1 kg) |
| G | Good general appearance | Q3 | M & B best lines (2 kg) |
| H | Visual homozygosity | Q4 | M & B Central (15 kg) |
| Hd | Head discoloration resistance | Q5 | M & B Western (10 kg) |
| Ht | Height | RR | Root rot resistance |
| K | Good kernel type | Sa | Sawfly test |
| L | Lodging resistance | Sh | Shattering resistance |
| LR | Leaf rust resistance | SR | Stem rust resistance |
| LS | Loose smut resistance | TW | Test weight |
| M | Reasonable maturity | Y | Yield |

information on all aspects of potential parent varieties in making the selection.

In the second stage, the varieties are rigorously tested for field performance and quality. The third stage covers purification, increase, and distribution of the seed of a new variety.

A typical course of a wheat hybrid population in the generations following the cross is shown in Table 1.

### Stage I — early generation screening

Testing for milling and baking quality begins on about 60 g of seed produced by $F_4$ generation lines grown in the field in Canada. The same testing procedure is applied to $F_6$ and $F_8$ material. During this stage alternate generations are grown in greenhouses or in nurseries in New Zealand (or California) during the Canadian winter to provide an extra generation in one year and thereby accelerate the development process. Grain produced outside of Canada is not tested for milling and baking quality.

The quality screening tests (QS in Table 1) during this stage include the following:

- Grinding time test, used to measure grain hardness, is applied to grain from crosses in which a soft wheat parent has been used (Kosmolak, 1974).
- Falling number test is used to measure the susceptibility to sprouting, if post-maturation weathering has occurred (AACC method 56-81B, AACC, 1983).
- Flour yield as measured by milling test on the Brabender Quadrumat Junior Laboratory Mill.

- Flour protein content (AACC method 46-12 or NIR spectroscopy).
- Mixogram development time (MDT) as a measure of gluten strength (Voisey *et al.*, 1966).

On the results from the above quality tests, selection of the best lines is based on independent culling levels, and the quality index calculated as follows:

Quality index = 0.2 ($\Delta$flour yield) + $\Delta$ flour protein + $\Delta$MDT (for MDT$\leqslant$0.3) or + (0.7 − MDT) for MDT $>$0.3
where $\Delta$ = difference between sample and mean of standards.

In the final phase of Stage I two yield tests (A and B) are carried out. The grain from these two tests is subjected to more extensive quality testing. In the A test about 100 new varieties from the breeding programme, along with four or five current varieties, are grown at five locations and two replicates. The varieties are screened for agronomic traits and the grain of successful varieties from different locations is composited for the Q1 quality testing. The actual tests that are used are listed in Table 2. Successful varieties from the A test are promoted to the B test. In this test, 21 or 22 varieties are grown at seven locations and three replicates. Quality testing at this stage (Q2 and Q3 tests, Table 2) is quite extensive. QS, Q1, Q2 and Q3 quality tests are carried out by the laboratories attached to the breeding stations.

**Stage II — the cooperative test**

The second stage of testing is the cooperative (C) test. This test is organised over two geographical regions: the central C test covers Manitoba and eastern Saskatchewan (generally referred to as the rust area), and the western C test covers western Saskatchewan and Alberta. The central test uses 10 locations and the western, eight. Normally a variety will be in the C test for three years. In the first year it will be in only one C test — the one for the area in which it was developed. In years two and three it will usually be tested in both the central and western (18 locations). For example, varieties with improved rust resistance required by the eastern prairie region would start in the central C test only, whereas solid-stem varieties (saw-fly resistant) would start in the western C test. In addition to the experimental varieties, Marquis (primary standard) and four or five current varieties (secondary standards) are included in all tests to provide data for comparative purposes.

The grain of each variety from different locations is composited for quality testing which is carried out in three laboratories: the Grain Research Laboratory of the Canadian Grain Commission, the wheat quality laboratory of the Agriculture Canada Winnipeg Research Station, and the wheat quality laboratory of the Department of Plant Science, University of Manitoba. The quality tests applied at this stage are the Q4 and Q5 tests listed in Table 2.

Data from the C test is reviewed each year by three

**Table 2. Milling and baking quality tests.**

Q1 Tests
- Flour yield (Buhler Experimental Mill; AACC method 26-20)
- Flour protein content (NIR calibrated against AACC method 46-12)
- Falling number (AACC method 56-81B)
- Mixograph development time, MDT (Voisey *et al.*, 1966)
- Amylograph viscosity (AACC method 22-10)
- Farinograph absorption (AACC method 54-21)
- Baking test
  1. Remix (Tipples and Kilborn, 1974) — 15 ppm bromate
  2. Remix (Tipples and Kilborn, 1974) — blend (50% soft wheat)
- Quality score[1]
  - Calculated using deviations from mean of standards
    = flour protein + 0.2 (flour yield) + 0.2 (farinograph absorption)
    + 0.2 (remix loaf volume) + 0.2 (remix blend loaf volume) + MDT,
    if MDT$\leqslant$0.3 or + (0.7 − MDT), if MDT$>$0.3

Q2 and Q3 Tests
- Flour yield (Buhler Experimental Mill; AACC method 26-20)
- Flour protein (NIR calibrated against AACC method 46-12)
- Flour ash content (AACC method 08-01)
- Mixograph development time. MDT (Voisey *et al.*, 1966)
- Amylograph viscosity (AACC method 22-10)
- Falling number (AACC method 56-81B)
- Farinograph test (absorption, DDT, MTI; AACC method 54-21)
- Baking test
  1. Remix (Kilborn and Tipple, 1981a)
  2. Remix blend (Kilborn and Tipples, 1981a)
- Quality score (as per formula in Q1 tests)

**Table 2 cont.**

Q4 and Q5 Tests
Wheat Tests
- Grade (Canadian grading system)
- Test weight (kg/hL)
- 1000 kernel weight
- Protein content (AACC method 46-12)
- Ash content (AACC method 08-01)
- Falling number (AACC method 56-81B)
- Amylase activity (AACC method 22-07)
- Flour yield
  1. Buhler Laboratory Mill
  2. Allis-Chalmers Laboratory Mill

Flour Tests
- Ash content (AACC method 08-01)
- Flour colour (Kent-Jones Colour Grader)
- Protein content (ACC method 46-12)
- Protein loss on milling (wheat protein — flour protein)
- Wet gluten content (AACC method 38-11)
- Starch damage (Farrand, 1966)
- Amylograph viscosity (AACC method 22-10)
- Gassing power (AACC method 22-11)
- Amylase activity (AACC method 22-08)
- Yellow pigment content (AACC method 14-50)
- Farinograph test (AACC method 54-21)
- Extensigraph test (Holas and Tipples, 1978)
- Baking test
  1. AACC straight dough (method 10-10A) — 0 ppm bromate
  2. AACC straight dough (method 10-10A) — 10 ppm bromate
  3. Remix (Kilborn and Tipples, 1981a) — 0 ppm bromate
  4. Remix (Kilborn and Tipples, 1981a) — 15 ppm bromate
  5. Remix (Kilborn and Tipples, 1981a) — 15 ppm bromate + 2% salt
  6. Remix (Kilborn and Tipples, 1981a) — blend (50% soft wheat flour)
  7. Canadian short time process (Kilborn and Tipples, 1981b)
  8. Sponge and dough process (Kilborn and Tipples, 1968)
- Baking strength index (Tipples and Kilborn, 1974)

[1]Developed by Dr R.J. Baker, Department of Crop Science, University of Saskatchewan, Saskatoon, SK.

national Expert Committees on breeding, quality, and diseases. An entry may be rejected by any of the three committees after one, two or three years of testing. If a variety receives the support of all committees in the third year, its breeder may submit an application for licensing.

**Stage III — licensing and seed distribution**

Canadian licensing requirements ensure that only varieties considered to be potentially beneficial to Canadian agriculture may be grown. According to the Canada Seeds Act, no varieties of seeds may be sold unless licensed by the Federal Minister of Agriculture. The actual licensing body is the Plant Health and Plant Products Directorate of Agriculture Canada. Any person or institution can apply to license a variety provided they have Canadian data indicating the variety is superior to present varieties, and have the support of recognised agricultural committees.

During the three years the variety is in the C test, the plant breeder also initiates the final stage of varietal development. He first ensures the purity of his seed stock, and then starts to multiply it. About one ton of breeder's seed is usually available at the time the variety is licensed. The breeder's seed is usually sold to SeCan (a non-profit association of members from all segments of the seed industry (seed growers and seed companies) who are also assigned the rights for distribution of the variety in Canada and abroad). Further multiplication of this seed is carried out by the Canadian Seed Growers Association (CSGA), the official pedigreed seed agency in Canada. Most CSGA members are also members of SeCan. Seed increase can also be carried out by members of CSGA who are not members of SeCan but this is normally done under contract with SeCan members. Seed increase is carried out in the area of adaptation of the new variety. SeCan has advantages over individual seed growers in being able to promote its varieties (by advertising) and to collect royalties on behalf of the developing organisation. Currently, Agriculture Canada is not collecting royalties on its varieties but Canadian universities are. The procedure for distribution of pedigreed seed in Canada may change in the near future when the legislation on Breeders' Rights (now before parliament) is enacted.

## DISCUSSION AND CONCLUSION

The major quality requirements of Canadian bread wheats derive from the 'equal to Marquis' specification of the grading system. In this regard, a key property is dough strength. In the screening process, strength is determined by tests such as the mixograph, farinograph, and extensograph. Additional information on strength is obtained from the mixing requirements in the baking tests and from the loaf volume obtained in the blend baking test. We realised some time ago that wheat varieties can be too strong. In baking tests that use mechanical dough development, such varieties require undesirably long mixing times for optimum development. Also, such varieties usually perform very well in the blend baking test but are rather poor when baked without dilution with a weaker flour. Canadian practice has been to select varieties that fall into a narrow mid-range of dough strength — varieties that are not too short or too long in mixing requirements. The narrow target adds a major constraint to the breeder.

Dough strength is closely related to protein content. Canadian wheats require a reasonably high protein content (c.13-14%) for optimum strength. Above that level, strength does not always increase with protein content. Indeed, there is evidence that under some field conditions, strength actually decreases with increasing protein content (Bushuk *et al.*, 1978).

Another important characteristic of Canadian bread wheats is that they perform well under many different baking conditions. This wide tolerance of many different baking procedures can only be ascertained by subjecting the sample to a large variety of baking tests. In the C test, samples are baked under eight different baking tests.

In recent years, resistance to sprouting (low alpha amylase activity) has become an important characteristic in our quality screening. The large number of tests (wheat falling number and amylase activity and flour amylograph viscosity, gassing power and amylase activity) used to detect susceptibility to sprouting damage attest to the importance of this characteristic in Canadian bread wheats. There have been several examples where a variety was rejected because of susceptibility to post-maturity sprouting. Breeders have taken special steps to incorporate sprouting resistance into our wheat varieties. In 1980, we licensed our first variety, Columbus, which has extra genes (from RL4137) for resistance to sprouting. The search for additional genes for sprouting resistance is continuing.

The electrophoresis test (Bushuk and Zillman, 1978) has been used on several occasions to check the identity of varieties in a composite of the grain submitted for quality testing. This test eliminates mislabelling and admixing errors. The possibility of using this test to provide information on quality is under active investigation in Canada and elsewhere.

Finally, it is up to farmers to decide whenever they wish to grow a new variety. The changeover to a new variety may be quite rapid, depending on how much incentive there is for the farmer to change. If his present variety is susceptible to rust, a new resistant variety would be very popular. The percentage area of one of our most popular recent varieties, Neepawa, which was licensed in 1969, increased rapidly to more than 61% of the annual wheat acreage by 1981.

Wheat breeding is a lengthy process, taking more than 10 years from the time of the initial cross to the commercial production of a new variety. Throughout the process the plant breeder relies on the assistance and advice of many people — plant pathologists, entomologists, chemists, physiologists, agronomists, marketing agencies, industrial users, and seed growers. One improved variety can return manyfold the investment in its development.

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## SYMPOSIUM DISCUSSION

Dr K. Ringlund, Agricultural University of Norway

What does the mixograph value that you can use on 60 grams of wheat relate to? Is is more like a sedimentation value, or is it related to farinograph or extensograph?

Is the index made up by excluding anything which is below a certain number in any of your tests, or is it from an average for the tests?

Bushuk

The mixograph test is a dough mixing test much like the farinograph, except that we use only 10 gm of flour. The mixograph dough development time gives an indication of gluten or dough strength.

The quality index has been developed by a statistical computer expert, Dr Bob Baker. He has gone through the many years of data — 20 to 40 years on many different varieties — and has developed a linear regression equation with 3 or 4 different variables which is used to calculate the quality index. A cut-off value based on experience is used to retain or reject varieties. The key is the final stage of testing where we have 8 different baking methods, plus physical dough tests and analytical tests.

Dr D.S.C. Wright

Are there any quality tests applied to your utility grade wheats?

Bushuk

No. Originally it was to be a class that gave the breeders a chance to go for yield as the key. However, having said that, there is basically only one variety in the utility class, Glenlea, so the quality of the Canada utility class has become equivalent to the quality of Glenlea. Any new varieties to be licensed into this class will probably be similar in quality to Glenlea.

Wright

Is there a thrust to breeding triple M wheats?

Bushuk

Yes, this is a new development in Canada within the last 6 months. We have created a new class called the Prairie Spring class with the intention of breeding wheat varieties intermediate between soft and hard wheats — intermediate in hardness, protein content and gluten strength. In practice, we have not been able to get a variety to fit the specifications that we set up. The first variety that was licensed into this new class, HY320, a bearded semi-dwarf variety, high yielding in comparison to our red spring wheats, fits the new class in terms of protein content and gluten strength, but not in terms of grain hardness. It is basically a soft wheat so we are trying to change this variety to medium hardness. Our marketing people feel there is a place for this class of wheat in some of the currently expanding export markets in the world, in competition to ASW.

Dr C.J. Petersen, USDA, Washington

Will the new tests you are coming up with to identify varieties help in getting away from physically identifying wheat?

Bushuk

Yes. We are just facing up to the problem of farmers smuggling in high-yielding varieties from the USA — varieties such as Marshall, Oslo and Era which are not visually distinguishable from CW red spring varieties, but do not meet the quality requirements. In Manitoba alone last season, there was almost half a million ha of this class of wheat. The Canadian grain commission has adopted an interim measure whereby this grain will be handled by a system similar to the one used in Australia — the grower will declare the name of the variety upon delivery to the silo and this will be monitored by electrophoresis.