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A COMPARISON OF HARD RED WINTER AND HARD RED SPRING WHEATS

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FOREWORD

The assumption that hard red spring wheats as a class are superior to the hard red winter wheats is rather common. One basis for this assumption is the price differential in favor of the spring wheats which often exists at terminal markets such as Chicago, Buffalo and New York city, The following flour quotations, New York city, July 19, 1939, show the price differential on these data:

Hard red spring, $4.10 to $4.35 per barrel.
Hard red winter, $3.85 to $4.00 per barrel.

The assumption that the hard red spring wheat has better quality has generally gone unchallenged. While Dr. R. K. Larmour served as visiting professor at Kansas State College 1938-'39, he made a careful study of the pertinent opinions expressed by various writers, as well as data found in papers dealing with the testing of wheats and flours. Doctor Larmour is peculiarly fitted to make this comparative study because of his long experience with the hard red spring wheat in Canada and because of the opportunity to study the quality of the hard red winter wheat while working temporarily in Kansas. He decided that it was best in the time available not to make further laboratory measurements, but limit the study to a critical examination of knowledge which already exists. The information which Doctor Larmour has assembled should be of great value not only to the milling and baking trades, but also to the wheat producers and those engaged in wheat improvement.

July 23, 1939.

L. E. CALL,
Director, Kansas Agricultural
Experiment Station.

A Comparison of Hard Red Winter and Hard Red Spring Wheats[1]

An Examination of Pertinent Opinions and Data

By R. K. Larmour[2]

INTRODUCTION

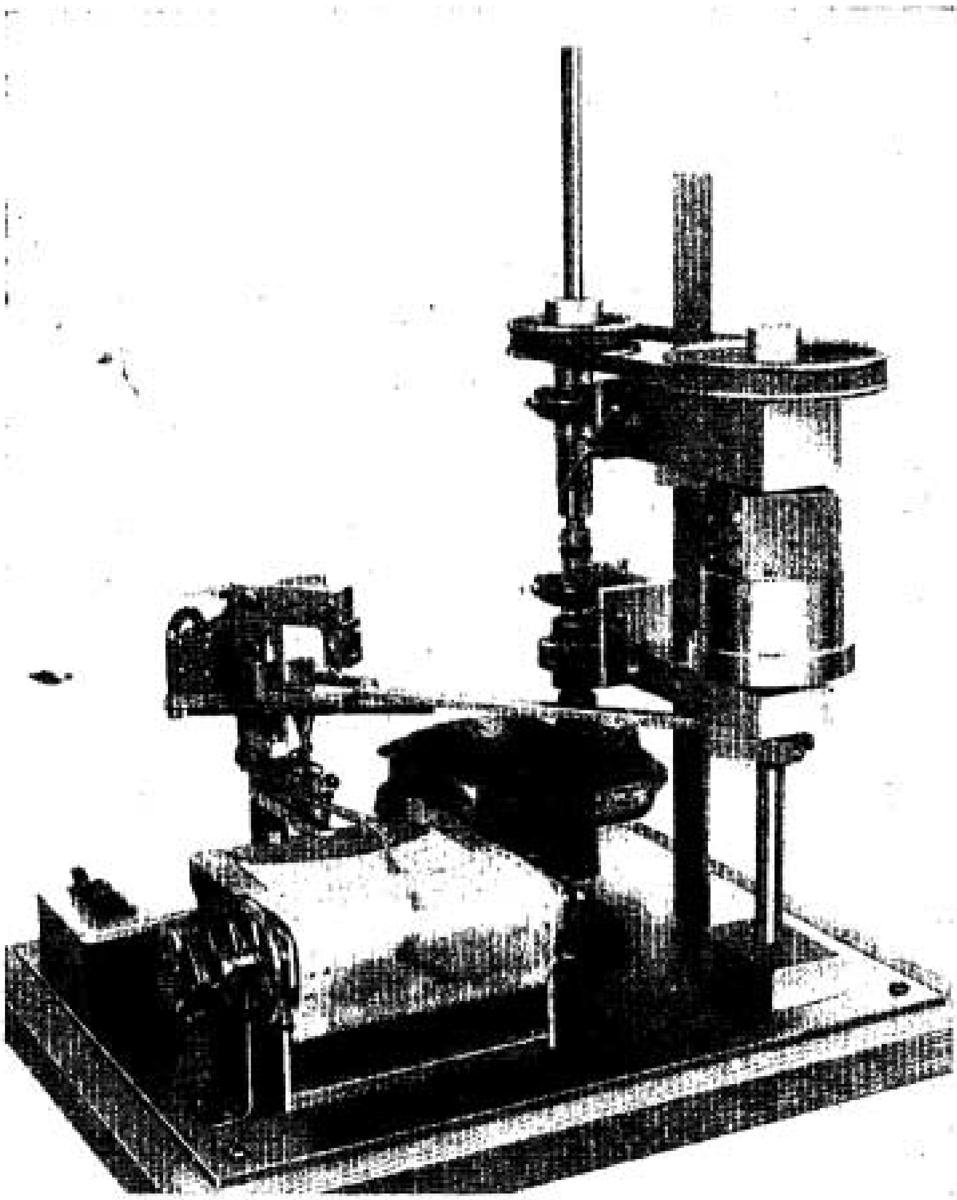
In the course of forty years the hard red winter wheat flour industry has advanced from a position of insignificance to one of dominance in the United States. At the turn of the century the meager amount of hard winter wheat that found its way to Kansas City or to Minneapolis mills was looked upon with suspicion and disfavor. The flour produced from it was yellow in color; it was a "harsh" flour which the bakers did not understand how to handle; with the baking practices in vogue at that time, practices suited to soft wheat flours or to the broadly tolerant hard spring flours of the Northwest, it gave indifferent results.

With the advent of bleaching as an integral part of the milling process the color was reduced to a satisfactory degree of "creaminess" and attendant to bleaching, the flour was "mellowed" to such a point that it handled reasonably well. As the volume of production in the Southwest increased and exceeded that of the Northwest, greater quantities of hard winter flours were offered to bakers, and in time they learned that these flours possessed excellent breadmaking characteristics. Today, the hard winter wheat flours compete actively and effectively with the hard spring wheat flours in all parts of the United States and now command a greater share of business.

The question of the relative qualities of the two wheat flours has arisen friequently and it has been tacitly assumed that flours milled from hard winter wheat are of inferior quality. Even those who are specifically interested in winter wheats have accepted this belief. Yet in spite of this belief, the fact must be faced that the use of winter wheat flours has steadily increased during the past quarter century. It would hardly be correct to attribute this increase entirely to the fact that the hard winter flours have usually sold at a discount. This has been an important contributing factor in their introduction to large-scale commercial bakeries, but the continuance of their use by these bakeries must be attributable to the fact that they have proven satisfactory.

Price considerations may account for a temporary redistribution of supplies, but such changes are unlikely to become permanent in a free country unless the proper quality is found present.

1. Contribution No. 66, Department of Milling Industry.
2. Visiting professor of Milling Industry at Kansas State College, 1938-'39.



The Swanson-Working recording micro mixer used in the determination of the physical properties of doughs. This machine was designed and perfected by Dr. C. O. Swanson and Dr. E. B. Working, of the Department of Milling Industry, Kansas Agricultural Experiment Station.

The theory might be advanced that the quality of bread has decreased, but there is little evidence to support this view. On the contrary, there are many who would maintain that the quality of bread produced with hard winter flours has materially improved in the course of the last twenty years. Thus the question of the relative qualities of hard winter and hard spring flours is of more than academic interest. It springs out of commercial trends and practices and therefore merits attention from the strictly practical point of view.

In comparing varieties of the same class of wheat it is possible to grow those varieties under almost identical soil and weather conditions, but in comparing two classes such as the hard winter and hard spring classes this "standardization" is difficult. Optimum conditions for one class are usually not suitable for the other and consequently one or the other is grown at a disadvantage. Even though the two classes were grown side by side the comparison would have little significance except as an indication of the lack of relative adaptability to those particular soil and climatic conditions. For instance, spring wheats grow poorly in Western Kansas, but the winter wheats are well adapted to those climatic conditions. It would be obviously wrong to make comparisons of these two classes on the basis of samples raised side by side in that area. Again, although both classes are grown fairly satisfactorily in Minnesota, South Dakota, Nebraska, and even as far north as Montana, there seems little doubt that one or the other is better adapted.

Bailey (1914) reported such a study for the crops of 1912 and 1913 in Minnesota. His data indicate that the spring wheats almost invariably were higher in protein content than the winter wheats produced under comparable conditions. Such a comparison could be used to appraise the comparative strengths of the two classes, but not the "quality" unless their different protein contents were taken into consideration in analyzing the data.

The data and other information concerning these two classes of wheat are widely scattered. They consist of, first, various expressed opinions based on general observations and experience; second, surveys of crop characteristics in which several classes of wheat are included; third, incidental comparisons derived from data in studies not primarily concerned with comparing spring and winter wheats, but in which both classes have been included for the purpose of making the study applicable to bread flours as a whole, and, fourth, studies in which various properties other than baking characteristics have been investigated. In most of the papers under the third and fourth headings, comparisons of the two classes have not been made specifically by the original authors. Many of the data, however, are suitable for inclusion in a review such as this. There is no possibility of doing more than to compare them for each individual laboratory as the methods have varied from time to time and between laboratories.

In this review of some of the pertinent work on the subject, direct citations and summaries of the data will be given, together with references to the original publications so that any interested reader may refer back to them. This does not purport to be an exhaustive review of the subject, and doubtlessly many publications have been overlooked. It represents merely what has come under the author's observation during the course of several months' reading on this subject. The most that can be hoped is that it is a fairly representative cross-section of the total available information.

OPINIONS BASED ON TRADE PRACTICES AND EXPERIENCE

Frequently the opinions expressed by those regarded as authorities in their own field have carried more weight than the published data of lesser known men. It is important, therefore, to review briefly what has been said about the relative values of hard winter and hard spring flours.

Jago and Jago (1911) in their classic book on breadmaking, describe American spring patents as "hard, dry flours, containing a high proportion of a very elastic gluten which only slowly softens during fermentation. They have high water-absorbing capacity, white color with comparatively little yellow, or bloom, in the bread. They produce a very bold loaf of good texture, with yellow crust that shows no foxiness. The bread tends somewhat rapidly to become hard and dry and is comparatively flavorless. It is a doughing flour, but it may be used in rapid sponges or one-third in long sponges." With regard to Kansas hard winter patents they state that they are "very similar in character to the spring American flours of Minnesota. The gluten runs fully as high, but is rather softer and softens more rapidly during fermentation than the hard spring flours. The color is generally good, in many samples being marked by a much fuller yellowness than in the American spring patent. Flavor is usually good and the bread fairly moist. They may be used for sponging, and also answer well as doughing flours for mixing with very weak, flavory varieties." They give the proximate analyses of these flours as follows:

TABLE I.—PROXIMATE ANALYSES OF AMERICAN HARD WINTER AND HARD SPRING FLOURS. (Jago and Jago, 1911)

	Total protein.	Soluble in water globulin.	Soluble in alcohol gliadin.	Insoluble glutenin.	Dry gluten.
Spring Patent	12.64	2.60	4.81	5.23	13.05
Spring Bakers	14.95	1.58	6.08	7.29	14.99
Winter Patent	8.77	1.45	3.63	3.69	8.89
Winter Bakers	10.86	1.31	4.43	5.12	11.00

It should be noted that the protein contents of flours given by Jago and Jago (1911) show the winter wheats much lower than the spring wheats. This is doubtlessly a reflection of the average run of the two classes coming to hand at that time. In view of the fact that the winter wheats averaged 29 percent lower in protein, it is surprising that they were held in as good repute as they were.

Bailey (1925), after reviewing the work that had been done with various classes of wheat, stated:

"The common wheat clases (thus omitting club and durum) may be rated in the following order so far as gluten content and baking strength are concerned: (1) Hard red spring; (2) hard red winter; (3) soft red winter; (4) white wheat. Compactum or club wheats rate lower than the common wheat varieties of the white wheat class. There is substantial overlapping insofar as these properties of the individual parcels of wheat of the several classes are concerned. Thus certain lots of any class may be superior to the average of the next higher class. Soft wheats, rating low in baking strength, may be superior for other purposes, such as cracker and biscuit and pastry production."

Swanson (1930) made a survey of European milling needs and interviewed a number of representative millers in the most important of the wheat-importing countries. Some of his remarks are particularly pertinent to this discussion and are therefore cited verbatim.

"It seems to be the general impression in Europe that the hard winter wheats, especially those exported from the United States, do not furnish the strength required in European milling mixtures, at least they do not have the same effect as equal percentages of Canadian wheat. On the other hand, it was pointed out that European millers prefer our hard red winter wheat to wheats of similar classes exported from Argentina because the export wheats of the United States are cleaner and are more uniform in quality. . . .

"The hard red winter wheats shipped from certain of the Gulf ports have a good reputation in European markets, but the hard red winter wheats of the United States shipped from Atlantic seaports are not in such high standing. The reason for the good reputation of the hard red winter wheat moving out of Galveston in certain years is due to the fact that the wheat moving there for export is largely of country run origin and has not been subjected to extensive mixing. On the other hand, the reason for the lack of quality in much of the wheat exported from Atlantic ports is, first, that the bulk of these wheats comprise the wheats not desired for domestic consumption in the large interior markets of Kansas City, Omaha and Chicago; and second, because a certain proportion of the wheat in the export mixture is wheat grown in territory that produces a type of wheat that has inherently poor baking strength. The reputation of the United States wheats shipped from Montreal is the poorest, and some buyers will not accept United States wheat from that port. . . .

"The fact that the European miller looks for strength in imported wheat cannot be overemphasized. This is clearly indicated by the existing preference for the lower grades of Canadian wheat in comparison with the corresponding lower grades from the United States. . As a rule, No. 3 Manitoba is considered to have the same value for blending purposes as No. 2 hard winter, and No. 2 Manitoba the same as No. 1 hard winter."

These observations and conclusions were corroborated by Shollenberger (1936), in another review of wheat requirements in Europe. He stated that:

"European millers consider hard spring wheats from Canada and the United States to be the strongest in baking quality. But no hard spring wheat from the United States has been offered in recent years. Hard winter wheat from the United States is also given a high quality rating, but it is considered slightly inferior to Canadian spring wheat. If milled by itself, it more nearly fits the European standard of quality for bread flour than does any other type of wheat. It is therefore a very useful type of wheat in all European countries where the importation of foreign wheat is not confined to a small percentage of the total requirements. . . .

"The long-time demand outlook for hard winter wheat, the principal type exported from the United States in the past, will be favorable, providing its price is lowered to that of wheats of similar quality from other exporting countries. Although the import demand for bread wheats in recent years has been considerably reduced by the milling restrictions placed on the use of foreign wheat in many of the leading wheat-importing countries, the reduction in demand has been chiefly for the soft types of wheat. Wherever there is a market for bread wheats, hard red winter, because of its desirable milling and baking qualities, will be given favorable consideration along with Canadian and Argentine wheats, provided it is offered at a somewhat similar price."

Speaking of millers' preferences in Europe he states that "United States hard winter wheats are well liked and are preferred to Argentine wheats, but are generally considered to be worth from 3 to 4 percent less than No. 2 Manitoba wheats. There have been times, however, when hard winter wheats have brought a higher price than No. 2 Manitoba. . . . The Argentine, Danubian, and Russian wheats are considered to be very variable in quality, whereas the Manitobas and hard winters are rather uniform in quality. . . . A miller stated that 35 percent was the maximum quantity of hard winter he could use in his milling mixture, 65 the maximum of Manitoba wheat, 35 the maximum of Argentine wheat, and 10 percent the maximum red durum. . . . Another miller stated his mixture varied according to the relative price and availability of the various types of wheat, but that usually it ran about as follows in percentage: 10 domestic, 50 Manitoba, or (25 Manitoba and 25 hard winter), 30 Argentine, and 10 Danubian wheat."

In Denmark "hard winter wheats from the United States are suitable for bread flours and can be used at prices 3 to 4 percent above prices for Plate wheats."

In France, "a wheat mixture consisting of 70 percent domestic wheat and 30 percent United States hard red winter is generally considered suitable for the production of flour; but if the percentage of foreign wheat used is between 30 and 15 percent, it is considered necessary to include some foreign wheat of stronger baking characteristics; and if less than 15 percent of foreign wheat is used, all of it must be of the best quality."

In Germany, "drastic restrictions imposed on the importation of foreign wheat since 1931 have made it necessary for German millers to use the highest quality obtainable for a high proportion of the foreign wheat. Some hard winter and the better types of Argentine wheats can be used in mixtures that contain 30 percent of foreign, but the greater proportion of foreign wheat must be of a quality equal to No. 1 Manitoba. Actually, however, very few mills in recent years have been able to use as much as 30 percent of foreign wheat. The regulations and restrictions made the importing of grain so difficult and troublesome that most millers use the fewest types and the smallest quantity of foreign wheat that will meet their needs. This can be accomplished by using only the very highest quality wheats obtainable; No. 1 Hard Manitoba is being demanded almost to the exclusion of all other foreign wheats. In demanding the best wheat obtainable, price is of relatively little importance to the German miller. . . .

"One miller was of the opinion that United States hard winter wheats were worth 20 percent less than Manitoba wheats. Another said that from the standpoint of effect on quality, 10 percent of Manitoba in their milling mixtures was equivalent to 15 of hard winter, whereas another thought that 30 percent of Manitoba was equivalent to 40 percent of hard winter. By some millers special types of Plate wheats are preferred to hard winter. United

States northern spring wheats are rated by German millers as being among the world's best quality wheats."

In Dutch mills "United States hard winter is the only wheat that the Dutch mills grind without mixing with other wheats, Argentine wheats are considered too weak and Canadian wheats too strong for milling alone. . . . United States No. 2 Hard Winter is considered to be about equal in quality to No. 3 Manitoba."

In Poland "if the importation is to be used by itself, United States wheat or flour of the ordinary hard winter export type is satisfactory, but if it is to be used with domestic wheat or flour, only importation of the highest quality are suitable."

In Spain "Manitoba wheat is generally considered the most suitable type for blending, with the domestic wheats and United States hard winters the second most suitable."

In Sweden "Canadian wheats of Manitoba No. 1 grade are considered to be the most suitable and they are being purchased, regardless of price, almost exclusively. . . . The pastry trade of Sweden and the other Scandinavian countries demands a strong flour. United States hard winter wheats and hard winter flours were considered about ideal for this purpose."

In Switzerland "under conditions that permit the miller full freedom of choice in the wheats he uses, a milling mixture that is considered to be typical of Swiss milling practice is one consisting of 30 percent Canadian, 20 percent United States hard winter, 25 percent Argentine, and 25 percent domestic and other wheats. Another mixture reported as being suitable consists of 50 percent No. 1 and 2 Northern Manitobas, 30 percent United States hard winter, and 20 percent Swiss wheat. . . . Canadian wheats are first in preference and United States hard winters second."

Summing up Swanson's and Shollenberger's observations, it appears that, European millers in general consider hard winter wheats good, but distinctly inferior to the hard spring wheats of Canada and the United States, especially for blending with weaker wheats.

Brabender (1932) compared hard winter and hard spring flours, and stated that German millers get good results in respect to loaf volume and texture with Kansas wheat. They noticed, however, that the sensitivity of these wheats to mechanical abuse was higher, while their fermentation tolerance was shorter than that of the Northwestern and Canadian types. In a later publication Brabender (1934) commented that—

"The hard winter wheat flour develops very quickly in the mixer whereas the hard spring flour takes a much longer time. A flour with a very short developing time in the Farinograph also needs a shorter time to attain its best gluten-ripeness." (During fermentation.)

Recently, Horace Ward (1939) commented on American winter and Manitoba as follows:

"Dark hard and hard types from the Gulf need 17 percent moisture and break down rather more readily than Manitobas, . . . The 1937 wheat was not as strong as Manitoba, but had quite good supporting value and was only a little inferior to the Vancouver types.

"In the 1938 crop there was a slight falling off in strength, but since Vancouver Manitoba has also fallen considerably, present hard winter is superior to Vancouver wheat below No. 1. It has been useful in the blend recently, as without Atlantic Manitoba, large quantities of supporting wheat have been necessary."

Fisher and Jones (1937) described the characteristics of various types of wheat entering into world commerce. Of the hard red winter wheat, he stated:

"The typical, pure varieties of hard red winter wheat, of which Turkey and Kanred are outstanding, are at their best only relatively slightly inferior in quality to Marquis, though differing strikingly from Marquis in certain respects. [Hard red winter wheats] have lower bushel weight and lower protein than Marquis, but they are not at all inferior in milling characteristics. They give, in fact, a surprisingly high flour yield of lively, granular flour. Such flour has as high water absorption, but not quite so extensive a fermentation tolerance as that from Marquis, and though giving an excellent loaf when baked alone, has less carrying power for weak flours. For a number of reasons, including varietal impurity, climatic and cultural variations, commercial hard red winter wheat, as exported, is never as fine as would be expected, from these considerations. The flour is definitely inferior in strength to that from high grade Manitoba, is a barely adequate gasser, the dough is not tough, although generally of satisfactory handling properties, including good spring and extensibility. Hard red winter wheat flour requires fairly long fermentation, but it has a more limited tolerance than Manitoba. As far as blending is concerned, hard red winter wheat is regarded as a neutral or filler wheat, Manitoba is classed as strong and English as weak. Hard red winter wheats neither carry weak wheats nor need much support from strong wheats. Hard red winter wheat has a leaning toward strength rather than weakness. There is no class of wheat which requires more careful testing of individual parcels, except perhaps Argentine and Russian. Hard red winter wheats from the Gulf ports have a much better reputation in European markets than those from the Atlantic ports, and the preference is certainly well founded."

From this brief survey of "expressed opinions" it is evident that there is a widespread belief that the hard red winter wheats, while of good quality, are not to be regarded as equal to either American or Canadian hard red spring wheats. It is generally accepted that they are superior to Argentine wheats in quality.

These opinions are based on experience with the various types of wheat as actually received for use. They, therefore, express the commercial evaluation of them per se. These ideas are no doubt responsible for the general acceptance of the belief that the hard winter wheats are actually inferior to the hard spring wheats in baking *quality*. It is possible that these dicta, based on commercial experience, ought to be accepted with certain reservations because it is well known that the hard winter wheats that actually get into export channels tend to run lower in protein than Canadian export wheats. If that were true it would explain to some extent why they are regarded as poorer for the European miller and baker who buy these wheats for their *strength,* for their ability to raise a blend containing low strength domestic wheats to an acceptable level. Naturally, low-protein hard winters would not be expected to be as efficient as high-protein hard springs, even though their inherent *qualities* were equal.

Although there is not a great amount of data available regarding the protein content of export wheat from the United States, the data of Coleman, *et al.* (1930), for the crop of 1926 give an indication of the relative protein levels of various classes of wheat exported. The average values are shown in Table II below.

TABLE II.—AVERAGE PROTEIN CONTENTS OF CANADIAN HARD SPRING EXPORT AND VARIOUS CLASSES OF UNITED STATES EXPORT WHEATS. CROP OF 1926. (From the data of Coleman *et al.*, 1930)

CLASS OF WHEAT.	Number of samples.	Average protein content of wheat, percent.
Canadian Hard Red Spring	135	13.14
American Hard Red Spring	14	12.78
American Hard Red Winter	34	10.91
American Soft Red Winter	40	10.26
American Soft White Wheat	30	10.94

The average value of the hard red winter wheats exported from the crop of 1926 was 16.9 percent lower in protein content than Canadian spring exports and 14.6 percent lower than American spring wheat exports. If this was a representative year it is not to be wondered at that European millers regard the hard springs as superior to the hard winters. From the commercial point of view such low protein wheats must be considered low in quality because they do not possess strength enough for satisfactory blending. They possess no excess or surplus strength; they have only enough to qualify as bread flours if milled as they are. For use as blending wheats they may justly be regarded as low in quality because they are not well suited to the purpose for which they are purchased. Rut it ought not be concluded that because the wheats are low in *strength* they are poor *quality* except insofar as the term quality is used to designate *suitability* for a specific use, in this instance blending with weak, soft wheats.

THE MEANING OF QUALITY

Baking quality, in the strict sense, might be defined as the measure of the *capacity of a flour to fulfill the predictions made on the basis of its protein content.* For instance, one expects to obtain an excellent loaf of bread of fine grain and texture, bold oven-spring, pleasing crust color, and good volume with flour of 12-percent protein content. If an unknown flour of 12-percent protein, baked with the same procedure gives a loaf of poor texture or color or volume or all of these, it seems justifiable to conclude that its quality is low. It evidently lacks the intrinsic capacity to produce the kind of bread required. On the other hand, if the unknown flour gives results comparable to the standard, it is regarded as of good quality. Thus it can be seen that *quality* is a relative term which depends largely on the standard by which it is judged.

Quality, used in this sense, may be affected by two factors, namely, intrinsic or inherent factors associated with the hereditary determiners in the germ plasm of the wheat plant, and extrinsic, or imposed factors such as drought, disease, frost, weathering, heating, etc. The first set of quality factors are unaffected by environmental conditions and give rise to what might be called primary quality. The second set of factors usually become effective only during the later part of the growth period and thus modify the primary or inherent quality, usually, but not always, in a detrimental fashion. Both the primary or inherent quality and the secondary or acquired quality are appraised in the same manner, by comparison with known standards. There can be no absolute quality. In this review the baking data studied will be limited to data obtained on sound samples of wheat and, consequently, there will be no discussion of secondary or acquired quality factors. Wherever the term *quality* is used it will be used in the sense discussed above.[3]

There are two other applications of the term quality which ought to be discussed here because it is the indiscriminate use of these terms synonomously with inherent quality, that has been responsible for much of the confusion among cereal chemists regarding the meaning of the term.

Suitability of wheat for a certain method of milling, or of its flour for a particular baking technique is often taken to be a quality factor, as indeed it may be. It would clarify the language of the cereal chemist greatly if it were agreed to use some other term for this factor. By doing so it would be clearly distinguished from the more fundamental *quality* factor. It might be designated *suitability* or *specific adaptability,* the latter being preferred because it implies that the factor applies only to certain cases and is not to be regarded as universal. It is readily seen that the evaluation of *specific adaptability* is difficult and that the standards by which it may be estimated will vary from place to place and from time to time.

Preference of individuals for certain classes, grades, or varieties may also enter into the customary appraisal of quality. This is of almost universal usage with all sorts of commodities. Personal likes, based on long use rather than on actual comparisons, cause people to regard the preferred thing as of a superior quality. This factor should be clearly recognized in attempts to appraise wheat qualities because it can so easily obscure the correct deductions. It is often closely associated with specific adaptability because a miller, for instance, having used only one type of wheat for many years may be convinced in his own mind that since he knows exactly how to handle the one sort that he likes and prefers, any other type, even though of equal or better quality, would be unsuitable or not adapted to his particular needs. Thus the matter of *preference* is a real factor in the estimation of general wheat quality and ought to be

3. There is another legitimate use of the term quality. It may be applied to various grades of flour when they are to be compared with each other. For example; a sixty percent patent flour is rated higher in quality than a second clear taken from the same mill run. In this case the inherent quality of the wheat is modified by the extrinsic factor of milling fractionation. However, it might be noted that even in flour grades one could appraise inherent quality by comparing the same fractions of different mill mixes.

recognized by those who attempt to ascertain trade opinions on this subject. It is extremely difficult to assess this preference with any accuracy. Usually founded on long-established custom, preference is liable to change suddenly as a result of some incident, such as failure of supplies or an abrupt change in price.

Instead of lumping all these factors into one inclusive term "quality," it would make this whole subject clearer if three terms were used, namely; *fundamental quality, specific adaptability,* and *preference,* having the connotations discussed above. It would also be a sensible thing to keep clearly in mind the concept of *strength* as applying to the quantity of protein available in specific sample of wheat or flour. This idea was ably presented by Blish and Sandstedt (1935), who suggested that strength and protein content be regarded as synonymous, and distinct from quality.

When *strength* or protein content, *fundamental quality,* and specific *adaptability* are all taken together in the appraisal of wheat or flour, one obtains an estimate of the *utility value* of the sample. This is usually regarded as the quality too, but this use of the term creates confusion and misunderstanding, especially when it is desired to arrive at the evaluation of fundamental quality. A little reflection will show that *utility value* ought not be used synonymously with quality. Swanson (1938) resorted to the simile of the rope to illustrate the difference. Two ropes made from the same quality hemp cord, one four-ply, the other eight-ply, possess the same fundamental quality, but greatly different utility values. Their usefulness depends on the quality of the material, the amount of material, and the suitability of the final product for a given purpose. It is easy to think of uses to which the smaller rope would be better adapted than the larger one, and in those instances the *utility value* depends principally on adaptability.

Even when the utility value can be proven suitable, a wheat or flour may be rejected on account of personal preference. Nothing can be done about preference. It must be regarded as the prerogative of the purchaser to buy what he likes. But personal preferences should not be admitted in the evaluation of either utility value or fundamental quality.

This rather long discussion of terms has been deemed necessary because there is considerable confusion in their use. Failure to differentiate clearly in their use has led to certain obvious errors of interpretation of baking data.

COMPARISONS OF HARD RED SPRING AND HARD RED WINTER WHEATS ON THE BASIS OF BAKING QUALITY

The most comprehensive of the earlier investigations of quality of the various classes of American wheats were those conducted by the United States Department of Agriculture and reported upon by Thomas (1917) and Shollenberger (1923). Some of the baking data from these studies are given graphically in figure 1.

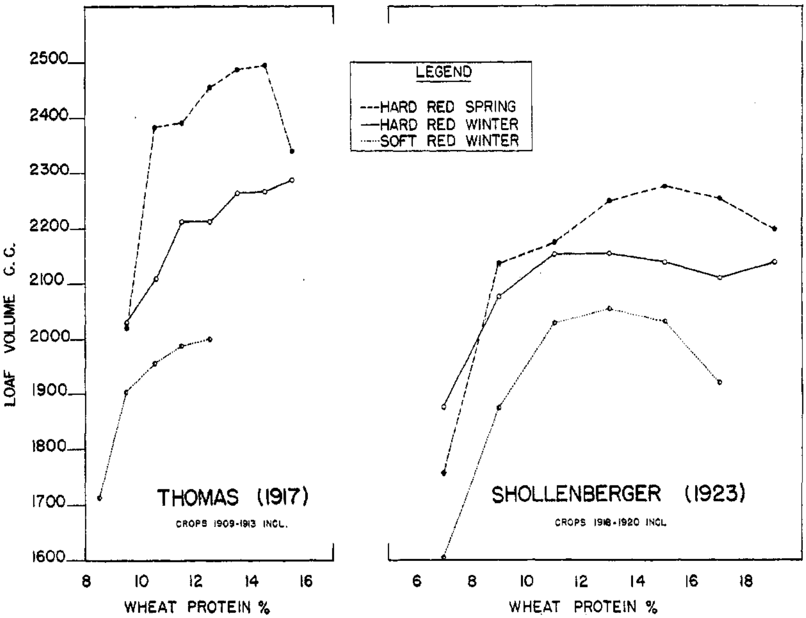


FIG. 1.—A comparison of the loaf volumes obtained at different protein levels from hard red spring, hard red winter and soft red winter wheats.

The data of Thomas (1917) indicated definitely that the hard red spring wheats were superior in baking quality to the hard red winter wheats, except at the lower protein level.

Shollenberger's (1923) data point to a similar conclusion, but it should be noted that the two classes appeared to be equal in the three lowest protein ranges, namely from "8 percent and lower" to "10 to 12 percent," roughly from the lowest protein levels to about 11 percent. From that point on, the hard red winters gave no further increase in loaf volume as a result of increasing protein content, and indeed actually decreased slightly while the hard red spring flours continued increasing in loaf volume up to about 15 percent protein content. Thus Shollenberger's data indicate that the hard red spring flours were actually superior to the hard red winter flours only in the protein ranges above "10 to 12 percent."

Thomas' loaf volumes for the low protein range were smaller than those of Shollenberger for the corresponding range, but in the higher protein ranges they were much greater. As details of the baking formulas and procedures used were not given in the publications referred to, it is impossible to state any reason for these differences.

The data summarized by the graphs in figure 1 were obtained from very large numbers of samples, representing in all, eleven crop years, and therefore ought to be rather convincing. These studies doubtlessly did much to establish the idea that the hard red winter wheats should be regarded as inferior to the hard red spring wheats in baking quality. However, these data support the strange conclusion that the hard red spring and hard red winter wheats are practically equal in quality at the extremes of the protein range, but different in the intermediate ranges.

From the work of Larmour (1931), Aitken and Geddes (1934), Finney and Barmore (1939), and Larmour, Working and Ofelt (1939), it is known today that the relation of loaf volume to protein content is almost, if not quite linear. The curvature previously thought to exist resulted from the use of inadequate baking formulas. Experimentally milled flours of high protein content require potassium bromate or other oxidizing substances to cause proper development of the dough during fermentation; otherwise they remain "gluten-bound" and fail to respond properly to proofing and baking.

It is unfortunate that in much of the earlier data published it is necessary, in attempting a comparison of the baking qualities of two classes of wheat, to compare baking results obtained with samples at different protein levels. This involves the consideration of two variables simultaneously, which is a difficult task indeed. For instance, if hard red spring flour at 13.5 percent protein gave loaf volume of 2,250 c.c., and hard red winter flour at 11.5 percent protein gave loaf volume of 2,100 c.c., how is one to judge which is higher in inherent baking quality? The 13.5 percent flour is unquestionably higher in *strength* because it actually has more protein and makes the larger loaf, but is the *quality* of its protein any better than that of the lower-protein flour? That is what has to be decided if one is going to compare these flours on a quality basis. It might be asked if a 150 c.c. difference in loaf volume could be expected from a 2 percent difference in protein. If this were deemed a reasonable expectation, the two flours would have to be considered equal in quality, though different in strength. Obviously one might try to compute or estimate the probable loaf volume of either of the flours in terms of the protein content of the other. For lack of better information, one could refer to the data of Thomas or of Shollenberger, for a means of making such an estimate.

Suppose it were decided to estimate what loaf volume the hard red spring flour might be expected to give at the protein content of the hard red winter flour, 11.5 percent. Taking Thomas' data, it can be observed that in the range 11 to 13.5 percent protein, one percent protein accounts for about 40 c.c. change in loaf volume. From Shollenberger's data it appears that 1 percent protein accounts for only 25 c.c. change in loaf volume over this range. Probably the mean, 32.5 c.c., would be better than either. Apply this to our hypothetical case, hard red spring flour of 11.5 percent protein might be expected to give a loaf volume of 2,185 c.c. This value being greater than that actually obtained with the hard red winter flour of 11.5 percent protein, one would be inclined to conclude that the hard red spring flour was superior to the hard red winter sample in quality, as well as in strength.

Admittedly, such procedure is fraught with hazards. It takes no account of probable differences due to various seasons, location, or laboratory techniques. And yet it might be asked whether it is not better to chance these errors, than merely to stare at the data as given and hazard a guess about the quality of the flours.

Although, in the light of recent knowledge, the technique employed in most of the earlier investigations of baking quality must be regarded as inadequate, it is nonetheless interesting to examine this earlier work in order to ascertain how well-based was the belief that hard red spring wheats are superior to the hard red winter wheats in baking quality.

Ladd and Bailey (1910) studied the 1908 and 1909 crops of North Dakota, Montana and Minnesota, and concluded that:

"Hard winter wheats rank second in point of baking strength, although many of the hard red winter wheat samples were better in this respect than the average of the hard spring wheat classes. There is no hard and fast line of division, so far as quality is concerned, between flours milled from wheats of this class and the hard spring wheats."

Some of their data are shown in Table III.

TABLE III.—AVERAGE OF THE MORE IMPORTANT TESTS MADE ON HARD SPRING AND HARD WINTER FLOURS. CROPS OF 1908 AND 1909. (Ladd and Bailey, 1910)

CLASS AND YEAR.	Wheat protein, percent.	Flour protein, percent.	Absorption, percent.	Loaf volume, c. c.	Crumb color.
1908.					
Hard Red Spring	14.19	13.00	54.2	2,307	97.0
Hard Red Winter	13.69	12.41	56.2	2,292	97.0
1909.					
Hard Red Spring	15.52	13.86	51.6	2,482	95.6
Hard Red Winter	14.26	13.48	53.0	2,358	94.0

1. Protein was given as N × 6.25.

For the 1908 samples, there was a difference of only 15 c.c. in loaf volume to be accounted for by 0.6 percent protein, which would indicate no difference between the two classes of wheat in quality. But in the 1909 samples, the hard spring samples averaged 124 c.c. higher in loaf volume than the hard winter samples, a difference much too great to be attributed to the difference in protein, which was only 0.4 percent.

This same publication contains an interesting comparison of milling and baking data on hard winter wheats grown in the northwest and the southwest states. These data are given in Table IV.

TABLE IV.—COMPARISON OF AVERAGE TESTS ON HARD RED WINTER WHEAT SAMPLES GROWN IN NORTH DAKOTA, SOUTH DAKOTA, MONTANA AND MINNESOTA, AND SAMPLES GROWN IN THE AREA 97° TO 101° MERIDIAN AND SOUTH OF 42° LATITUDE. (THIS AREA INCLUDES SECTIONS OF NEBRASKA, KANSAS, OKLAHOMA AND TEXAS) CROP OF 1908. (Data of Ladd and Bailey, 1910)

SOURCE.	Total flour, percent.	Flour protein, percent.	Absorption, percent.	Loaf volume, c. c.	Crumb color.
Northwest	70.59	12.75	57.5	2,163	95.5
Southwest	71.62	13.61	57.3	2,428	99.7

1. Protein calculated on basis, N × 6.25.

The authors concluded from these data that:

"The hard winter wheats grown in the northwestern states, even though plump, dark and hard, did not yield a flour of as high baking quality as samples from Nebraska and Kansas."

Of even greater interest is the comparison of data for the hard red spring wheat and the hard winter wheat from the southwest, both of the 1908 crop. The values were: hard springs, loaf volume 2,307 c.c., protein 13.00 percent; hard winter, loaf volume, 2,428 c.c., and protein 13.61. The hard winters were, on the average, 121 c.c. higher in loaf volume and only 0.61 percent higher in protein. This would support the conclusion that the hard winter wheats were superior to the hard spring wheats in quality in that season.

Ladd and Sanderson (1910) reported on spring and winter wheats grown in North Dakota in 1910 and concluded that the spring wheat was higher in strength than the winter wheat. Average loaf volumes were 2,503 c.c. and 2,225 c.c. for spring and winter wheat, respectively. The protein contents were not stated.

Bailey (1913) made a study of the 1911 crop of Minnesota and Montana. The Montana samples consisted of both spring and winter wheats and from these he drew the following conclusions regarding the relative values of these two classes of wheat:

"The hard red spring wheat flours excelled both (hard red winter and soft red winter wheats) with respect to strength, . . . In other words, the baking quality of the hard spring wheat samples raised in Montana was nearly equal to the same class raised in Minnesota, but the flours milled from Turkey type hard winter wheats were distinctly inferior in the majority of cases."

TABLE V.—COMPARISON OF MONTANA HARD RED WINTER AND HARD RED SPRING WHEATS OF THE CROP OF 1911. (Averages from Bailey's 1913 data)

CLASS.	Number of samples.	Total flour, percent.	Flour protein, percent.	Absorption, percent.	Loaf volume, c. c.	Color score.
Hard Red Spring........	14	72.8	11.36	56.3	2,516	98.9
Hard Red Winter.......	8	73.8	10.02	56.8	2,348	98.0

Bailey's (1913) data, given in Table V, show that the hard spring samples were, on the average, 168 c.c. greater in loaf volume and 1.34 percent higher in protein, than the hard red winter samples. A correction for protein, based on the data of Thomas and Shollenberger, could account for about 44 c.c. of this difference, and therefore these data support Bailey's conclusion as cited above.

Another comparison of springs and winters was made by Bailey (1914), using samples grown in Minnesota in the years, 1912 and 1913. A summary of the data obtained with samples of the two classes of wheat grown in the same localities, is given in Table VI.

TABLE VI.—DATA ON MINNESOTA HARD SPRING AND HARD WINTER WHEATS GROWN IN THE SAME LOCALITIES. CROPS OF 1912 AND 1913. (Bailey, 1914)

CLASS AND YEAR.	Number of samples.	Total flour, percent.	Flour protein, percent.	Absorption, percent.	Loaf volume, c. c.	Color score.
1912						
Hard Red Spring........	16	69.5	10.93	59.0	2,423	97.9
Hard Red Winter.......	16	69.8	9.44	55.7	2,152	98.0
1913.						
Hard Red Spring........	6	72.8	11.05	61.0	2,467	99.7
Hard Red Winter.......	6	70.8	10.50	59.9	2,409	99.2

Bailey commented on these results as follows:

"The winter wheat samples of the crops of 1912 and 1913 were inferior in baking quality to the spring wheats grown under the same conditions in almost every instance. Many of the winter wheat samples were decidedly poor in quality, while otherwise equal to the average of the hard spring wheats." . . .

"It will be observed that the winter wheats of the crop of 1912 were generally inferior in quality to the spring wheats grown in the same localities so far as protein content and baking strength were concerned. In certain instances the differences were not great. This was particularly true when the spring wheat was poor in quality. . . . The Minnesota-grown winter wheat samples were lower in average protein content and poorer in general quality than many samples of the same type examined by the author which were grown in sections of the southwestern states. For example, samples from central Kansas have been analyzed which contained from 14 to 15 percent of crude protein and were correspondingly high in baking quality. It is evident, therefore, that Turkey wheat grown in a more northern section is not necessarily of high quality, but that rainfall, humidity, and other climatic factors are of more importance than latitude."

Here again, the two classes of wheat were compared at different protein levels. However, there is no doubt that the 1912 spring wheat samples were distinctly superior to the hard winter samples; the difference of 1.5 percent in protein would scarcely account for the difference of 270 c.c. in loaf volume. But with the 1913 samples, it seems doubtful that the data justify the conclusion that the hard spring samples were distinctly superior to the hard winter samples.

The data given in Tables III to VI inclusive, dealing with the northwest crops of 1908, 1909, 1911, 1912 and 1913, show that the hard spring wheats were, in each year, on the average higher in protein than the hard winter wheats produced in the northwest, and therefore were *stronger*. In three of the five crop-years, they also appeared to be of better quality. The one comparison of southwest winter wheat and northwest spring wheat made on samples of the 1908 crop, showed that the former were superior to the spring wheat samples.

There seems to be little doubt that the high quality of southwestern winter wheats was well recognized at that time, and that the references to the inferior quality of hard winter wheats applied specifically to hard winter wheat grown in the northwest. If these references were generalized by some people, to embrace all hard winter wheats, the error must be attributed to faulty examination of the publications cited above.

Shollenberger and Clark (1924) published data obtained with pure line varieties and various other samples of all classes of wheat in the United States, over the period 1915 to 1921 inclusive. Doubtlessly, the data represented in figure 1 were derived from this study, but nevertheless the averages for the various classes of wheat may prove interesting and they are accordingly given in Table VII.

TABLE VII.—MILLING AND BAKING DATA FOR AMERICAN WHEAT CLASSES. Crops of 1915 to 1921, inclusive. (Averages from the data of Shollenberger and Clark, [1924]).

CLASS.	Number of samples.	Test weight.	Wheat protein, percent.	Flour yield, percent.	Absorption, percent.	Loaf volume, c.c.	Crumb.	
							Texture.	Color.
H. R. S., varieties	1,128	56.8	13.9	69.6	59.9	2,210	89.5	89.8
H. R. S., all samples	1,310	56.9	13.6	69.3	59.4	2,142	89.5	89.3
H. R. W., varieties	334	59.4	13.5	72.4	61.1	2,028	89.5	90.2
H. R. W., all samples	728	58.8	12.6	72.0	60.0	2,121	90.8	90.2
S. R. W., varieties	189	58.9	11.3	71.0	56.1	1,929	87.7	89.6
S. R. W., all samples	457	58.6	11.3	71.1	55.9	2,001	88.9	89.1
White Wheat, varieties	511	58.4	12.3	70.6	57.2	1,876	86.9	90.2
White Wheat, all samples	580	58.5	12.0	70.7	56.8	1,872	87.2	90.2

These data furnish no sound basis for concluding that the hard winter wheats are inferior to the spring wheats. Although the hard winters were inferior to the spring varieties, in the variety studies, they were superior in respect to the average of the classes. The hard winters were highest in test weight and in flour yield.

Much interesting information concerning the various classes of American wheat may be found in the United States Department of Agriculture bulletin on the "Milling and Baking Characteristics of World Wheats," prepared by Coleman and his collaborators (1930). They classified the samples tested into: (a) Pure varieties grown under known conditions, and (b) export samples obtained at point of loading. Some data on samples collected at point of unloading were also tested, but as they do not add materially to this particular discussion, they have been omitted from the summary given in Table VIII.

TABLE VIII.—MILLING AND BAKING DATA ON HARD RED WINTER AND HARD RED SPRING WHEAT SAMPLES OF THE CROP OF 1926. (Coleman *et al.*, 1930)

CLASS.	Number of samples.	Flour protein, percent.	Absorption, percent.	Loaf volume, c.c.	Crumb.	
					Color.	Grain.
H. R. S., varieties.......	14	15.32	61.8	2,291	86	92
H. R. S., cargoes........	14	11.96	58.2	2,156	87	91
H. R. W., varieties......	15	13.65	61.3	2,207	86	90
H. R. W., cargoes.......	34	9.89	57.7	2,176	88	91

Commenting on the variety studies the authors stated:

"From a baking standpoint all the flours milled from the spring wheat varieties exhibited excellent strength. The water absorption was high and fermentation tolerance was excellent, as were all the other factors entering into the scoring of a good loaf of bread. Moreover, the quantity of bread that could be baked from a barrel of flour by the method of baking used was high....

"The hard red winter wheat varieties showed a greater variation in milling properties than did either the hard red spring or the durum wheat varieties. ... The baking quality of the hard winter wheat varieties was variable mostly with regard to volume of loaf and color of crumb. As far as water absorption of the flour, fermentation time of the dough, and texture of the loaf are concerned, average to above average conditions prevailed with but one or two exceptions. Bread production was high, averaging 295 pound loaves per barrel of flour. On the average, a slightly better loaf of bread was obtained from the spring-wheat flours than from the winter-wheat flours."

Although the authors made no comments on the relative qualities of the export spring and winter samples, it can be seen from the data in Table VIII that the export wheat averaged very much lower than the varieties in protein, but did not show a commensurate decrease in loaf volume. The hard red spring wheat variety samples gave loaf volume 24 c.c. higher than the winter wheats, but they were also higher in protein by 1.67 percent. A reasonable correction for protein of 54 c.c. would leave the spring varieties 30 c.c. higher in loaf volume. In the export samples the hard red winter samples averaged 20 c.c. higher in loaf volume although they were 2.07 percent lower in protein than the hard red spring wheat samples. These data indicate that on the whole the hard winter wheats were of better average quality than the spring wheats.

Several less pretentious studies of the qualities of world wheats have been made. Among these might be mentioned, first, that of Pelshenke (1935), the data from which are summarized in Table IX.

TABLE IX.—BAKING DATA AND QUALITY VALUES OF SOME WORLD WHEATS. (Pelshenke, 1933)

DESCRIPTION OF SAMPLE.	Loaf[1] volume, c.c.	Crumb texture.	General baking quality.	Wheat protein, percent.	Gluten quality value, minutes.	Specific gluten quality, value.
Canadian No. 1	2,990	6	Excellent	17.4	117.5	6.74
Kansas	2,970	8	Good	14.0	104.3	7.45
Canadian No. 3 Nor	2,965	8	Very good	16.3	101.0	6.20
Canadian No. 2 Nor	2,800	8	Good	15.5	110.0	7.10
Canadian No. 1 Nor	2,750	7	Good	15.7	109.9	7.02
Australian	2,160	7	Very fair	12.1	42.6	3.55
French	1,955	8	Fair	10.6	36.0	3.40
German No. 2	1,900	6	Fair	10.4	29.9	2.88
German No. 2	2,200	6	Poor	11.8	30.2	2.56
Argentine No. 2	2,100	7	Poor	13.4	43.9	3.28
English No. 2	1,840	7	Poor	11.6	31.0	2.67
Danubian No. 2	1,730	3	Very poor	13.6	29.2	2.15

1. The baking tests were made at the Grain Research Laboratory, Winnipeg, Canada.

The Kansas wheat sample gave loaf volume equal to those obtained with the Canadian wheat samples, although the latter were all considerably higher in protein content. It was also in the same class with the Canadian wheats in respect to "gluten quality value."

In the same publication Pelshenke gave his estimate of the various classes of world wheats. This is shown in Table X.

These gluten quality values are really the "wheat-meal fermentation times." While cereal chemists are in disagreement as to the value of this test in assessing quality, these data are interesting as an indication of the opinion of a well known European cereal chemist.

Geddes (1937) reported on a study of various world wheats. Although he did not point out the relative values of the different classes, the data are interesting enough to be included here. Because this paper has not had wide distribution in the United States, the data are reproduced in Table XI in somewhat greater detail than would be necessary were the original publication readily available.

TABLE X.—GLUTEN QUALITY VALUES FOR SOME SAMPLES OF WORLD WHEATS (Pelshenke, 1933)

CLASS OF WHEAT.	Gluten quality test number.
	Min.
Northern Spring	160–280
Manitoba	80–240
Hard Winter	25–110
Russian	20–60
Barusso	25–50
Australian	25–35
Hungarian	20–40
Squarehead's Master	12–25

While it is reasonably easy to compare the one United States hard winter sample with the other hard winter samples because they are of about the same order of protein, it is difficult to compare it with the hard red spring samples because the latter are so much higher in protein. Fortunately it is possible to make an estimate of the relation between loaf volume and protein content of flour, for three of the four baking formulas in Table XII, by referring to the comprehensive study of Aitken and Geddes (1934). While it is recognized that the relationship of loaf volume to protein likely differs somewhat from year to year, it seems better to take the risk of this error than to depend on a casual inspection of the data.

Using this estimated loaf volume, one would conclude that the United States hard winter was equal to the United States dark Northern spring sample in quality by the male-phosphate formula, superior to it by the malt-phosphate-bromate formula, and inferior to it by the formula involving over-mixing. These conclusions would also apply if the average of the four spring wheat samples were considered. The reactions of the United States hard winter and the hard spring wheat flours to the different formulas were quite different, as would be expected. It is well known that American hard winters, as a rule, require more bromate than do the hard springs, and that they are less tolerant to severe mixing.

While these data show unquestionably that the hard spring samples were *stronger* than the United States hard winter sample, it would be extremely risky to conclude that they were superior in *intrinsic baking quality.*

An interesting series of comparisons of Southwest and Northwest commercial flours of the crop of 1938 is to be found in the report of

TABLE XI.—ANALYTICAL DATA FOR WORLD WHEATS. (Geddes, 1937)

Origin.	Description.	Predominating class.	Weight per 1,000 kernels.	Weight per bushel.	Wheat protein.	Total flour.	Flour analysis, 13.5 percent. Moisture basis.				Water absorption.‡	Mean loaf volume baking formula.				Notes on dough-handling properties.	Pelshenke disintegration time.
							Protein.	Ash.	Diastatic activity.*	Carotenoid† pigments.		Malt phosphate.	Malt phosphate bromate.	High yeast sugar.¶	M. P. B. over mixing.‖		
			g.	lb.	Percent.	Percent.	Percent.	Percent.	mg.	p. p. m.	Percent.	cm.‡	cm.‡	cm.‡	cm.‡		Min.
Argentina	Buenos Aires	Hard red winter	26.4	64.0	12.2	78.6	11.4	0.46	116	1.50	57.5	685	668	575	640	Good	140
Argentina	Bahia Blanca	Hard red winter	29.2	63.0	11.4	74.4	10.5	0.44	112	2.19	55.0	643	668	613	635	Good	84
Argentina	Upriver	Hard red winter	32.8	62.5	13.0	73.9	11.9	0.45	76	1.62	51.5	550	570	575	510	Fair but slackened badly	42
Argentina	Rosafe	Hard red winter	32.2	64.0	12.0	73.2	10.8	0.48	90	1.70	54.0	610	573	528	510	Good	79
W. Australia	F. A. Q	Soft white	38.8	64.0	9.8	75.6	9.2	0.39	94	2.52	51.5	540	530	530	493	Poor	42
S. Australia	F. A. Q	Soft White	34.6	61.5	10.5	74.6	9.6	0.39	90	2.27	51.5	568	580	565	545	Puttylike	72
Canada	No. 1 Hard	Hard red spring	28.3	65.2	13.8	76.5	13.5	0.38	100	1.81	58.5	723	875	760	930	Excellent	196
Canada	No. 2 Northern	Hard red spring	26.2	64.0	13.8	75.4	13.3	0.42	115	2.02	58.0	718	868	795	908	Excellent	171
Canada	No. 4 Northern	Hard red spring	26.3	64.5	12.5	74.1	11.9	0.45	152	2.05	59.0	738	795	670	730	Very good, tendency to slacken,	140
England	Red F. A. Q	Soft red winter	43.5	64.0	9.2	75.8	8.0	0.40	82	2.60	49.5	465	440	470	425	Extremely poor	41
France	Somme district	Soft red winter	46.4	63.5	9.6	77.6	8.2	0.42	82	2.30	47.5	495	475	508	460	Poor	45
Germany	Holstein district	Soft red winter	40.8	63.5	10.3	74.5	9.3	0.38	68	2.16	48.5	503	493	510	488	Poor	36
Hungary	Kalocsa district	Soft red winter	31.5	62.5	10.7	73.8	10.0	0.42	120	2.40	49.5	593	583	555	558	Fair	58
Italy	Variety Mentana	Soft red winter	33.[illegible]	61.0	9.7	76.3	8.9	0.46	64	1.34	50.5	460	473	548	470	Very poor	65
Italy	Variety Villa Glori	Soft red winter	27.5	60.0	9.1	74.6	8.1	0.39	58	1.49	49.5	463	465	490	448	Poor	61
Italy	Variety Fausto Sestini	Hard winter	37.2	62.0	10.7	75.2	9.3	0.45	66	1.88	52.5	490	478	498	480	Poor	73
Russia		Hard red winter	49.2	65.5	13.2	77.1	12.3	0.48	126	1.61	55.5	725	675	578	705	Very good	180
United States	No. 2 Hard Winter	Hard red winter	25.9	63.8	11.3	75.8	10.8	0.43	160	2.23	56.5	650	753	698	698	Excellent	58
United States	No. 1 Soft	Red winter	37.8	66.0	11.2	77.9	10.5	0.38	78	2.00	51.0	550	610	605	605	Fair	58
United States	No. 1 Dark Northern Spring		24.5	62.5	14.6	75.5	14.0	0.50	110	2.23	57.5	780	818	788	915	Excellent	200
Jugo-Slavia		Soft red winter	36.8	60.0	9.4	74.1	8.4	0.45	74	2.71	48.5	500	483	515	503	Very poor	44
		Range	21.9	6.0	5.5	5.4	6.0	0.08	96	1.37	11.5	320	435	338	505		159

* Diastatic activity is expressed as milligrams maltose per 10 grams flour, employing a temperature of 30° C. according to the method outlined by *Blish* and *Sandstedt*, Cereal Chem. 10, 189 (1933).

† Carotene was determined by means of a *Bausch & Lomb* spectrophotometer, using the method described by *Ferrari*, Cereal Chem. 10, 277 (1933).

‡ The water absorption recorded is that quantity of water which yielded a dough of the proper consistency at time of panning, using the maltphosphate formula.

¶ Basic formula and procedure except that 5 percent yeast, and 6 percent sucrose and 0.001 percent $KBrO_3$ are employed.

‖ The malt-phosphate-bromate formula with the doughs given a very severe mixing (3 minutes in a *Hobart-Swanson* mixer).

TABLE XII.—COMPARISONS OF HARD RED WINTER AND HARD RED SPRING WHEATS FROM VARIOUS PARTS OF THE WORLD, INCLUDING THE UNITED STATES. (Condensed from the Data of Geddes (1937) given in Table XI.)

ORIGIN.	Description.	Flour protein, percent.	Loaf volume.[1]			
			I.	II.	III.	IV.
HARD RED WINTER:						
Argentina	Buenos Aires	11.4	685	668	575	640
Argentina	Bahia Blanca	10.5	643	668	613	635
Argentina	Upriver	11.9	550	570	575	510
Argentina	Rosafe	10.8	610	573	528	510
Average of four Argentina		11.2	622	620	573	574
Italy	Fausto Sestini Variety	9.3	490	478	498	480
Russia		12.3	725	675	578	705
U. S. A.	No. 2 Hard Winter	10.8	650	753	698	698
HARD RED SPRING:						
U. S. A.	No. 1 Dark Northern	14.0	780 (652)[2]	815 (590)	788	915 (809)
Canada	No. 1 Hard	13.5	723 (615)	875 (686)	760	930 (841)
Canada	No. 2 Northern	13.3	713 (613)	868 (623)	795	908 (826)
Canada	No. 4 Northern	11.9	738 (694)	795 (708)	670	730 (684)
Average of three Canadian		12.9	725 (641)	846 (672)	742	856 (784)

(1) Formulas: I, Malt-phosphate. II, Malt-phosphate-bromate. III, High-yeast-sugar. IV, Malt-phosphate-bromate with overmixing.
(2) Estimates of probable loaf volumes at 10.8% protein content. These are based on estimates of the regression of loaf volume on protein content from the data of Aitken and Geddes (1934). Loaf volume per 1 percent protein: Formula I, 40 c.c.; Formula II, 70 c.c., and Formula IV, 33 c.c. No estimate of regression for Formula III could be made.

TABLE XIII.—COMPARATIVE BAKING AND OTHER DATA ON COMMERCIAL FLOURS MILLED IN THE SOUTHWEST AND NORTHWEST. CROP OF 1938. (Data of W. E. Long and Co., 1938)

CLASS.	Grade of flour.	Number samples included in average.	Average flour protein, percent.	Absorption, percent.	Average loaf volume, c.c.	Development time, farinograph, minutes.
Northwest	Short Patent bleached	19	12.55	63.2	876	9
Southwest	Short Patent bleached	18	11.88	60.3	902	5
Northwest	Standard Patent bleached	19	12.05	63.8	885	8
Southwest	Standard Patent bleached	18	12.14	60.5	904	5.5
Northwest	Short Patent unbleached unmalted	19	12.58	....	918	....
Southwest	Short Patent unbleached unmalted	14	11.83	....	906	....
Northwest	Long Patent unbleached unmalted	19	13.04	....	900	....
Southwest	Long Patent unbleached unmalted	12	12.08	....	927	....

the W. E. Long Company, Chicago, for the season of 1938. Very comprehensive baking tests were made, using various fermentation times with and without malted wheat flour and potassium bromate. The best loaf volumes were obtained with 2 1/2-hour fermentation in the cases of both the bleached and the unbleached, unmalted flours. With the latter, the best volumes for each class of flour were obtained on the average with 0.25 percent malted wheat flour and 2 1/2-hour fermentation. The data for the "optimum" baking method are given in Table XIII together with the average protein content of the various classes of flour.

Attention should be directed to the fact that the Southwest flour samples, were, on the average, considerably lower in protein content than the Northwest flours. Despite this they gave actual loaf volumes greater than those of the Northwest flours in most instances. The least noticeable difference was in the unbleached, unmalted, short patents where the protein of the Southwest flours was lower by 0.75 and the loaf volume by only 12 c.c. than the Northwest flours.

Water absorption of the flour was higher in all instances for the Northwest flours. If this were included in an estimate of general baking quality the difference between the two classes would tend to decrease somewhat.

INCIDENTAL COMPARISONS OF HARD WINTER AND HARD SPRING WHEATS AND FLOURS

There will be considered now various investigations not made primarily for the purpose of comparing spring and winter wheats or flours, but which included both classes for the evident purpose of having a wide range of bread flours represented. It may be assumed that representative samples were chosen as far as possible. In some of the studies cited, only one sample of each class has been included, while in others, each class has been represented by a number of samples.

In a study of the diastatic activity of flours, Rumsey (1922) used a number of spring and winter wheat flours of various grades. The baking data, protein content, and diastatic activity of these are given in Table XIV.

The baking formula used with these flours contained no diastatic supplement. It consisted of yeast 3.0 percent, sugar 2.5 percent, salt 1.5 percent, lard 2.0 percent, water as required. However, the fermentation period varied according to the behavior of the doughs and this would tend to reduce the difference due to differences in diastatic activity. The baking results, however, doubtlessly reflect, to some extent at least, the differences in diastatic activity and therefore it is difficult to make comparisons between the spring and winter wheat flours in this series. There were two spring wheat patent flours and one winter wheat patent flour that were very nearly equal in diastatic activity, the values being 131.9, 123.6 and 132.9 respectively. Comparing these, it is evident that the winter

TABLE XIV.—BAKING DATA, PROTEIN, AND DIASTATIC ACTIVITIES OF SOME SPRING AND WINTER WHEAT FLOURS. (Rumsey, 1922)

CLASS AND GRADE.	Flour protein, percent.	Absorption, percent.	Loaf volume, c.c.	Bread score.	Diastatic activity.
SPRING:					
Patent	13.81	59	2,160	100	211.8
Patent	15.32	60	2,000	97	204.1
Patent	11.96	61	1,735	91	131.9
Patent	11.04	59	1,820	90	123.6
First Clear	14.12	65	1,460	46	105.7
Second Clear	12.70	58	1,415	35	145.0
WINTER:					
Patent	11.34	60	2,010	99	248.2
Patent	12.76	59	1,870	91	132.9
First Clear	13.00	58	1,880	95	186.5
First Clear	14.83	58	1,630	56	132.6
Second Clear	14.37	59	1,295	32	116.2

wheat patent was superior to one spring wheat patent and approximately equal to the other in quality. For the patents of higher diastatic activity similar conclusions may be drawn. These data furnish no support for the idea that spring wheat flours are superior in quality to hard winter flours.

Rask and Alsberg (1924) in an investigation of the viscosities of various wheat flour starches, used samples of both spring and winter wheat flours. Milling and baking tests were made by W. K. Marshall of the Grain Division, Bureau of Agricultural Economics, United States Department of Agriculture. The baking data are shown in Table XV.

TABLE XV.—BAKING DATA AND PROTEIN CONTENT OF SOME SPRING AND WINTER WHEAT FLOURS. (Data of Rask and Alsberg, 1924)

DESCRIPTION.	Class.	Source.	Flour protein, percent.	Absorption, percent.	Loaf volume, c.c.
Straight flour	H. R. S.	N. Dakota,	9.49	59.7	2,090
Commercial patent	H. R. S.	Minnesota,	9.50	60.6	2,200
Marquis	H. R. S.	Idaho	12.42	65.3	2,150
Average of Springs			10.47	61.5	2,147
Straight flour	H. R. W.	Kansas	10.51	60.6	2,050
Commercial patent	H. R. W.	Kansas	9.80	60.3	2,220
Average of Winters			10.15	60.4	2,135

Comparing the straight flours, the winter was inferior in quality to the spring, but with the commercial patent flours, the winter was equal to the Minnesota spring flour and much superior in quality to the Idaho spring flour. No definite conclusion may be drawn from these data.

Continuing the study of wheat starches, Hermano and Rask (1926) used another series of flours which were also milled and baked by W. K. Marshall, in the Grain Division of the United States Department of Agriculture, Washington. There were only two samples of hard red spring wheat included in this series and one of these was "smutty." Therefore, any comparisons made from the data in Table XVI must be made with this in mind.

TABLE XVI.—MILLING, BAKING AND PROTEIN DATA ON HARD RED SPRING AND HARD RED WINTER WHEATS. (Averages from the data of Hermano and Rask, 1926)

CLASS.	Flour yield, percent.	Wheat protein, percent.	Loaf volume, c.c.	Crumb.	
				Color.	Texture.
Hard Spring	75.0	11.35	2,165	91.6	91.2
Hard Winter	76.5	13.00	2,265	87.6	89.2

Unless bromate was used in the baking formula, it is doubtful that 1.65 percent protein would account for a difference of 100 c.c. in loaf volume, and therefore the data indicate superiority of the hard winter flour. Heavy weighting of the crumb characteristics might reduce the quality difference indicated by loaf volume alone.

An investigation of the concentration of the various proteins in flour was conducted by Grewe and Bailey (1927) using commercially milled flours which included seven spring and three hard winter flours. A summary of their baking and protein data is given in Table XVII.

TABLE XVII.—BAKING AND PROTEIN DATA ON SOME SAMPLES OF SPRING AND WINTER WHEAT FLOURS. (Used by Grewe and Bailey, 1927)

CLASS.	Number of samples.	Flour protein, percent.	Loaf volume, c.c.	Texture score.
Spring	7	11.70	2,077	97
Winter	3	11.62	2,127	98

The average protein contents of the two classes of flours were so nearly equal that it requires no calculation to correct for this variable. The winter wheat flours, though slightly lower in protein content, were higher in loaf volume than the spring wheat flours.

In studying the effect of various methods of incorporating dry skim milk into bread doughs, Amidon (1926) conducted a number of baking tests with a hard spring and a hard winter flour. Both flours were baked by the same formulas with the variable factor being the method by which the dry skim milk was prepared before mixing into the doughs. The formula was typical of those used at that time and consisted of the following percentages: Sugar, 3.08; salt, 1.85; yeast, 2.31; shortening, 2.31; dry skim milk, 5.0; water as required; fermentation to suit the doughs. The average loaf volumes and total scores for the two flours are given in Table XVIII.

TABLE XVIII.—BAKING AND PROTEIN DATA ON ONE SAMPLE EACH OF HARD WINTER AND HARD SPRING WHEAT FLOURS. (Amidon, 1926)

CLASS.	Flour protein, percent.	Average loaf volume, c.c.	Average total score.
Spring	12.05	2,063	90.1
Winter	10.88	2,092	90.5

These data show that the hard winter flour, although lower in protein by 1.17 percent, produced larger loaves with better total score than the spring wheat flours, thus indicating that they were distinctly superior in quality.

Weaver and Fifield (1935) used both hard winter and hard spring wheat flours in a study of the effect of varying the mixing time of doughs. Some of the data pertinent to this discussion are given in Table XIX.

TABLE XIX.—EFFECT ON BREAD CHARACTERISTICS BY VARYING THE DOUGH MIXING TIME IN THE HOBART-SWANSON MIXER FROM ½ TO 3 MINUTES. (Weaver and Fifield, 1935)

TYPE OF FLOUR.	Length of mixture, minutes.	Loaf volume, c.c.	Crumb color.	Grain and texture.	Flour protein, percent.	Dough character.
Hard Red Winter Experimentally Milled	½	576	100	95	10.74	Undermixed.
	¾	571	100	100	....	Undermixed.
	1	577	100	105	....	Mixed smooth.
	1½	580	105	110	....	Mixed smooth.
	2	592	105	110	....	Mixed smooth.
	3	601	110	110	....	———
Average	....	583	103	105	....	
Hard Red Spring Experimentally Milled	½	569	90	80	12.82	Undermixed.
	¾	579	90	80	....	Undermixed.
	1	585	90	85	....	Mixed smooth.
	1½	607	95	90	....	Mixed smooth.
	2	667	105	100	....	Mixed smooth.
Average	....	608	95	88.3	....	

At the three lower mixing times, the hard red winter flour was about equal in volume to the hard spring flour and decidedly better in grain and texture. This relation reversed with the longer mixing times. On the average, the hard winter flour was lower than the spring flour, by 25 c.c. in loaf volume and 2.05 percent in protein. The hard winter flour in this case appeared to be superior to the spring wheat flour in quality.

A paper by Bohn and Bailey (1936) provides some interesting baking data, on both spring and winter hard wheat flours, which are presented in Table XX.

The Northwest spring wheat varieties were, on the average, very much higher in protein than either the "Minnesota" or Kansas flours, and since we have no idea concerning the relation of loaf volume to protein by the baking method employed, it is almost impossible to estimate what loaf volume might be expected at the protein level of the Kansas flours, namely at 12 percent. However, if it were assumed that Minnesota hard spring flours were not materially different in quality to the Northwest hard spring flours, it would seem likely that 1 percent protein was equal to a little more than 50 c.c. in loaf volume. On this basis, the Northwest flours might be expected to show 12 percent protein loaf volumes of about 570 c.c., a value well below the average for the Kansas flours.

If the "Minnesota" and Kansas flours are compared individually it is apparent that the latter are quite superior in intrinsic quality. The lowest protein Kansas flour had greater loaf volume than any of the four Minnesota flours.

TABLE XX.—BAKING, PROTEIN AND OTHER DATA WITH HARD SPRING AND HARD WINTER WHEAT FLOURS. (From the work of Bohn and Bailey, 1936)

DESCRIPTION OF SAMPLE.	Number of samples.	Stress (15 seconds reading).	Flour protein, percent.	Loaf volume.		Baking quality, score.	
				2-min. mix.	5-min. mix.	2-min. mix.	5-min. mix.
MEAN VALUE OF SOME NORTHWEST SPRING WHEAT VARIETIES							
Marquis	7	19.8	14.89	693	593	78.2	63.3
Ceres	7	19.4	14.98	987	598	78.8	62.8
Reward	4	16.9	15.63	783	579	86.3	56.4
Thatcher	6	20.2	15.45	751	625	85.5	65.2
Average	24	19.3	15.18	722	600	81.5	62.5
MINNESOTA FLOURS							
Ceres	1	19.9	11.30	510	490	61.0	49.0
Hope	1	19.0	11.80	515	485	60.5	47.5
Marquis	1	17.2	10.10	470	465	56.0	49.5
Thatcher	1	16.9	11.80	500	485	60.0	42.5
Average	4	18.3	11.25	499	481	59.4	47.1
KANSAS FLOURS							
	1	15.1	10.90	615	475	66.5	45.5
	1	16.7	12.80	665	500	70.5	44.0
	1	15.5	11.50	605	505	70.5	48.5
	1	16.3	10.40	635	535	70.5	52.5
	1	16.2	12.20	595	520	65.5	50.0
	1	16.0	13.90	700	545	75.0	53.5
	1	14.5	14.40	660	555	60.0	49.5
	1	18.0	10.10	560	490	86.0	58.0
Average	8	16.0	12.02	629	516	70.6	50.2

It is interesting to note that the Kansas flours showed much less tolerance to the longer mixing, than did the Minnesota flours. This would be regarded as confirmation of the well-known shorter mixing tolerance of the hard red winter wheat flours, were it not for the fact that the Northwest hard spring samples also showed large decreases in volume and score as a result of the longer mixing.

The data in Table XX, on the whole, support the conclusion that the intrinsic quality of the Kansas flours was equal or superior to that of the hard spring wheat flours.

Spring and winter wheats grown in Montana in the years 1933 and 1934 were tested by Whitcomb (1938) who found that the oven-spring of the spring wheat flours was nearly twice that of the winter wheat flours. A summary of his baking and other tests is given in Table XXI.

TABLE XXI.—BAKING AND OTHER DATA ON HARD SPRING AND HARD WINTER WHEATS GROWN IN MONTANA IN THE YEARS 1933 AND 1934. (Averages from the data of Whitcomb, 1938)

CLASS.	Wheat protein, percent.	Loaf volume, c.c.	Absorption, percent.	Crust color.	Crumb texture.	Boldness of loaf.	Oven spring.
Spring......	14.8	561	62.1	97.5	98.3	96.9	1.18
Winter......	13.8	510	59.8	98.3	95.6	93.7	0.60

The winter wheats were lower in protein on the average, lower in absorption, texture of bread, boldness of loaf and oven spring, and lower in loaf volume than the spring wheat flours. It could be concluded from these data that the winter wheats are slightly inferior to the spring wheats in baking *quality.*

Both spring and winter wheat flours originating in the United States were used by Malloch (1939) in a study of a new recording dough mixer. A summary of his baking data is given in Table XXII.

These data show evidence that there were large quality differences within the two classes of flours. Some of the winter samples were equal in loaf volume to some of the spring samples of much higher protein content. But the seven winter samples were all lower in protein and in average loaf volume than the spring samples. For a difference of 2.4 percent in protein, the average loaf volume difference of 116 c.c. does not appear too great for the malt-phosphate-bromate formula, and one would therefore hesitate to pronounce either of these classes superior in quality to the other.

Sandstedt and Blish (1939) used both spring and winter wheats in an investigation of sugar levels in laboratory baking tests. Many baking tests, involving variations of percentage sugar, and proofing procedures were made. As the sugar level did not have a pronounced effect on the baking results, the loaf volumes at all four levels have

TABLE XXII.—BAKING AND PROTEIN DATA ON SPRING AND WINTER WHEAT FLOURS. (Average values from the data of Malloch, 1939)

ORIGIN AND CLASS.	Flour[1] protein, percent.	Loaf[2] volume, c. c.
WINTER WHEAT FLOURS:		
Elevator lot	10.0	462
Elevator lot	10.7	502
Kansas	11.1	543
Iowa	11.2	473
Iowa	11.3	578
Elevator lot	11.7	528
Kansas	12.1	608
Average of seven	11.2	528
SPRING WHEAT FLOURS:		
Minnesota	12.6	607
Minnesota	12.7	671
N. Dakota	12.8	615
N. Dakota	13.0	677
N. Dakota	13.1	625
S. Dakota	13.7	593
Minnesota	13.8	696
Elevator lot	14.0	688
S. Dakota	14.2	554
S. Dakota	14.5	671
Elevator lot	15.2	684
Average of eleven	13.6	644

(1) One mixed spring and one white wheat sample have been omitted.
(2) Baked by the malt-phosphate-bromate formula.

been included in the averages shown in Table XXIII. The winter flours included two Kansas samples and the spring flours included one sample from Montana and one from Canada. The spring wheat flours were higher in protein than the Kansas flours, and gave greater loaf volumes as might be expected. Loaf volume differences between the two classes of flours, where the doughs were proofed to constant height, were considerably smaller than would be anticipated from their protein difference. When proofed to constant time

TABLE XXIII.—INVESTIGATION OF SUGAR LEVELS IN LABORATORY BAKING TESTS. (Sandstedt and Blish, 1939)

CLASS.	Baking method.	Flour protein, percent.	Average loaf volume all sugar levels, c.c.
Spring	No shortening, constant proof time	13.7	609
	No shortening, proofed to height		571
	Two percent shortening, constant proof time		660
	Two percent shortening, proofed to height		648
Winter	No shortening, constant proof time	12.7	554
	No shortening, proofed to height		575
	Two percent shortening, constant proof time		600
	Two percent shortening, proofed to height		621

the differences were 55 c.c. and 60 c.c., which were perhaps a little greater than would be expected for 1 percent protein difference, with the baking formula used. These data, on the whole do not indicate that the spring wheat flours were superior to the winter flours.

The data presented by Smith (1925) are interesting because he compared three grades of each class of flour, namely short patent, clear, and low-grade. No detailed baking data were given in this paper. The baking results were assembled into a "bread score" in which the various baking characteristics were weighted as follows: Loaf volume, 25 percent; height of break, 20 percent; shred of break, 20 percent; grain, 20 percent; and texture, 15 percent. These weighted values combined, gave the "bread score" which was shown graphically. The values were read from the graph and are given in Table XXIV, together with the protein data.

TABLE XXIV.—BREAD SCORES AND PROTEIN DATA FOR VARIOUS GRADES OF SPRING AND WINTER WHEAT FLOURS. (Smith, 1925)

Class.	Grade of flour.	Flour protein, percent.	Bread scores at various[1] fermentation periods—hours.					
			1.	2.	3.	4.	5.	Average.
Spring	Short patent	12.12	98	99	99	98	94	97.6
Spring	Clear	13.96	88	98	98	89	71	88.8
Spring	Low grade	14.29	76	97	87	96	96	90.4
Winter	Short patent	10.42	86	94	83	79	76	83.6
Winter	Clear	11.68	68	69	74	69	68	69.6
Winter	Low grade	13.00	60	63	67	67	63	64.0

1. Read from figure 2 of the paper.

With these bread scores there is nothing to do but accept them as estimates of the *utility value* of the flours. There is practically no information available regarding the effect of lower protein on bread characteristics in flours series of known uniform quality, and thus it is quite impossible to estimate a correction for protein. The *utility values* of these winter wheat flours were low, but whether that was owing to the protein being low in quality, or simply to the small amount of protein present, we cannot even surmise.

Swanson and Kroeker (1932) reported the results of cooperative baking tests on three varieties of hard winter wheat and one variety of hard red spring wheat. The ranking given these samples by eleven cereal chemists independently is shown in Table XXV.

These placings of the varieties were based on all the characteristics of the flours that were observed during the course of the test, and therefore represent what might be called the "general opinion" of the various operators. There is no doubt that the spring wheat was considered better than the hard winter wheats in this series of tests. Again it should be noted that the spring wheat flour was higher in protein than the others, although one sample of Kanred was of practically the same protein content as the Marquis sample.

TABLE XXV.—RANKING OF VARIETIES BY ELEVEN INDEPENDENT CHEMISTS. (Swanson and Kroeker, 1932)

VARIETY.	CLASS.	Flour protein, percent.	Number of chemists who placed the variety in these rankings.				
			1.	2.	3.	4.	5.
Marquis	Hard Red Spring	12.95	8	1	......	......	2
Kanred	Hard Red Winter	12.65	......	8	2	1	......
Kanred	Hard Red Winter	10.85	......	3	4	2	2
Blackhull	Hard Red Winter	11.30	1	4	4	2	......
Tenmarq	Hard Red Winter	10.85	3	1	2	3	2

DISCUSSION OF BAKING TESTS

It is somewhat difficult to summarize concisely the results of the foregoing investigations. One fact that stands out most prominently, is that in nearly all instances where spring and winter wheat flours have been used, the hard winter wheat flours were lower in protein content. This introduces a bias in favor of the spring wheats. There is no justification for attempting to compare the *intrinsic qualities* of these two classes of wheat without taking into consideration the differences in their protein contents. This would be analagous to comparing the work done by three men with that done by two men. If the work were the important consideration the comparison could be made easily on the basis of what was accomplished, but if one were interested in the relative capacities of the men to do work, it would be necessary to take into consideration the number of men working. Thus, while it could be expected that three men would accomplish more than two men usually, it might be found that the two men, on the average possessed the higher capacity to work.

The protein content of flour is analagous to the number of men working; it determines to a large extent what the flour may be expected to accomplish in bread making. But the end result cannot be taken as the measure of relative capacity for bread making unless it is weighted in some manner to compensate for differences in quantity of protein. Unfortunately there is not sufficient data available to enable one to make more than a very rough estimate of a correction for protein differences. However, in discussing certain of the foregoing studies, such estimates have been applied in cases where it seemed impossible otherwise to reach a conclusion.

The data examined provide evidence that the hard red winter wheats were equal or superior to the hard red spring wheats in a majority of the investigations. It would be a mistake, however, to think that these studies have had equal weight in influencing opinion. On the contrary, actual comparisons of the two classes of wheat were made in only a few instances. A few studies, based on large numbers of tests, and conducted by men well known in the field of wheat investigation, doubtlessly served to "fix" the belief that the hard winter wheats must be regarded as inferior in *quality* to the hard spring wheats, with the result that evidence to the contrary contained in many lesser studies received little attention. With the probable exception of Thomas' (1917) work the data published does not justify any such conclusion, if one considers *inherent quality* as being different from *strength.*

In addition to the fact that the conclusions drawn from the data were too sweeping, much of the earlier data may be questioned on the ground that the baking methods used in those studies were inadequate for testing the baking performance of either the hard spring or the hard winter wheat flours, especially those that were milled experimentally. It has been shown by Larmour (1931), and others that a "lean" baking formula, in which only sugar, yeast, salt, and water are used is not suitable for high-protein spring wheat flours. These flours require potassium bromate or some other similar acting substance to mellow the gluten. They also often need additional diastase to sustain yeast activity. Without these additional substances in the baking formula the lower protein samples perform relatively better than the higher protein samples and this has led to quite absurd conclusions.

Recent investigation of Finney and Barmore (1939), and Larmour, Working, and Ofelt (1939), indicate that when suitable baking formulas are applied to hard winter wheat flours, the loaf volumes obtained are a linear function of the protein content of the wheat or flours. The high-protein samples are most affected because by the older formulas they usually failed to exhibit the effect of their higher protein.

In the light of this knowledge the curved portions of the graphs shown in figure 1 must be regarded with a great deal of skepticism. As was stated earlier in connection with these data of Thomas, and of Shollenberger, the fact that there was practically no differences between the spring wheats and hard winter wheats at the extreme protein levels and great differences at the median levels throws doubt on the validity of the baking method employed in these studies. This appears to be an admissible conclusion in the light of the recent studies cited above.

It should not be concluded from the foregoing statements that all the earlier baking data ought to be disregarded. The inadequacy of the earlier formulas was most marked in high-protein experimentally milled flours. Much of the work reviewed here was done on commercial samples, many of which had been bleached. Many of the samples studied were of low or medium protein content. In such cases the "lean" baking formula might be expected to give fairly reliable results. It is even possible that the spring wheat flours in many of these studies were actually at a disadvantage on account of their higher protein. Larmour (1931) showed that with the "basic" formula of the American Association of Cereal Chemists, which was about as "lean" as could be, the loaf volume of spring wheat flours was related to protein content of wheat, in strictly linear fashion up to approximately 15.5 percent protein. This was for only one crop year. Unless this relation between protein and loaf volume differs materially for different years it seems unlikely that the probability of the hard spring wheats being penalized on account of high protein merits serious consideration.

While the foregoing data and discussion indicate that there has been little experimental evidence to support the general opinion that hard red winter wheats are inferior in quality to hard spring wheats, it would be a mistake to regard the two market classes as the same qualitatively. There is abundant evidence that they differ in characteristics. It is probable that in many instances these "differing characteristics" have been a confusing factor in comparisons of relative "baking quality." There are many instances of equality in efficiency with differences in characteristics. Usually it is easy to keep these two factors distinctly in mind. For instance, a fleet of freighting trucks and a railway train might haul the same amount of freight the same distance, in the same time, at the same cost, and they would be regarded as equally efficient. But no one would think of confusing their different physical characteristics with their efficiencies in attempting to evaluate the relative values of the freight services rendered. One might be preferred on the basis of personal tastes, but that is another matter entirely. With bread wheats it seems difficult to keep separate these two factors, but it must be done if we are to get a correct appraisal of the quality of the winter and spring wheat classes.

DIFFERENTIATING CHARACTERISTICS

Dough-mixing Time.—The time required to mix the flour and other baking ingredients to a smooth dough of proper consistency differs markedly for the hard spring and hard winter flours. In general, the former require considerably longer time than the latter. Attempts have been made to translate the characteristics of the dough development curves into terms of baking quality, but there is some doubt at present that this is possible. It seems more likely that the mixing characteristics as revealed in the mixing curves should be regarded as indications of varietal differences and, to some extent, of the protein level of the flour.

There has perhaps been a tendency to assume that because the winter wheats generally produce curves different in shape from those obtained with spring wheat flours, such curves indicate inferior quality. But that assumption is linked with the widely accepted belief that the spring wheats are superior in quality to the hard winter wheats, an assumption that at best, is but poorly founded on experimental evidence. It is more reasonable to assume that these two classes simply differ in this characteristic and that it is not necessarily related closely to baking quality except within the classes. Even within classes, much more information than is available at present is necessary before one can be safe in using this sort of data for more than distinguishing between classes or between varieties within classes.

The two types of instruments available for studying the mixing characteristics of flours are the Brabender Farinograph and the Swanson-Working Recording Dough Mixer. It is beyond the scope of this paper to describe these instruments in detail or to discuss their relative merits. It is generally believed that they measure somewhat different properties of flour, and that the curves require different interpretations in regard to some features. It is agreed that they both present a fairly accurate estimate of the mixing requirements of flour doughs. It is difficult to compare the curves made by one machine with those made by the other, but the curves of either alone may be used to gain considerable useful information regarding what may be described as the "physical properties" of the doughs.

Brabender (1932) made a study of hard spring and hard winter flours with a view to finding what type of flour is best suited to blending with soft European wheats. He stated in conclusion that:

> "Wheat and flours should be selected for export to Europe which have a speedy water absorption capacity and fast developing time and also remain long on their optimum consistency."

He expressed the opinion that flours showing slow developing curves would behave badly in blends with the European wheats which, as a rule, develop rapidly.

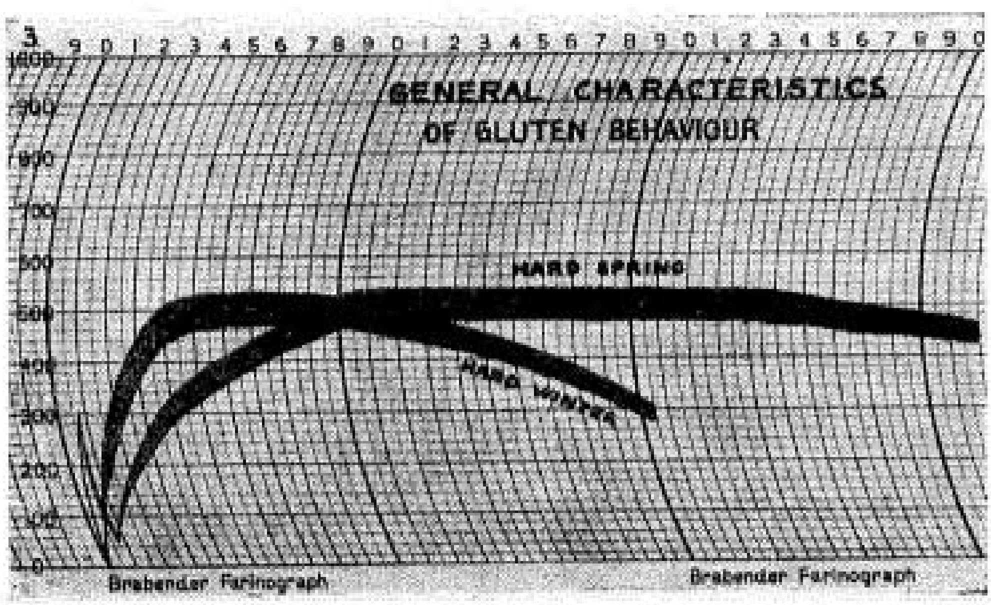


FIG. 2.—Average characteristics of American hard spring and hard winter wheat flours as shown by Farinograph curves.

Brabender (1934) presented two Farinograph curves to illustrate the average characteristics of American hard spring and hard winter flours. They are shown in figure 2. It should be noted that the time required for the curve to reach the highest point and the time during which it remains at this maximum consistency are less in the case of the winter wheat flours than in the case of the spring wheat flours. This seems to be typical of the two classes, although some exceptions to this general rule have been noted.

Curves obtained with the Swanson-Working Recording Micro-Mixer on series of pure-line winter wheat varieties at different protein levels are to be found in a paper by Larmour, Working, and Ofelt (1939). They are reproduced here in figure 3. The curves

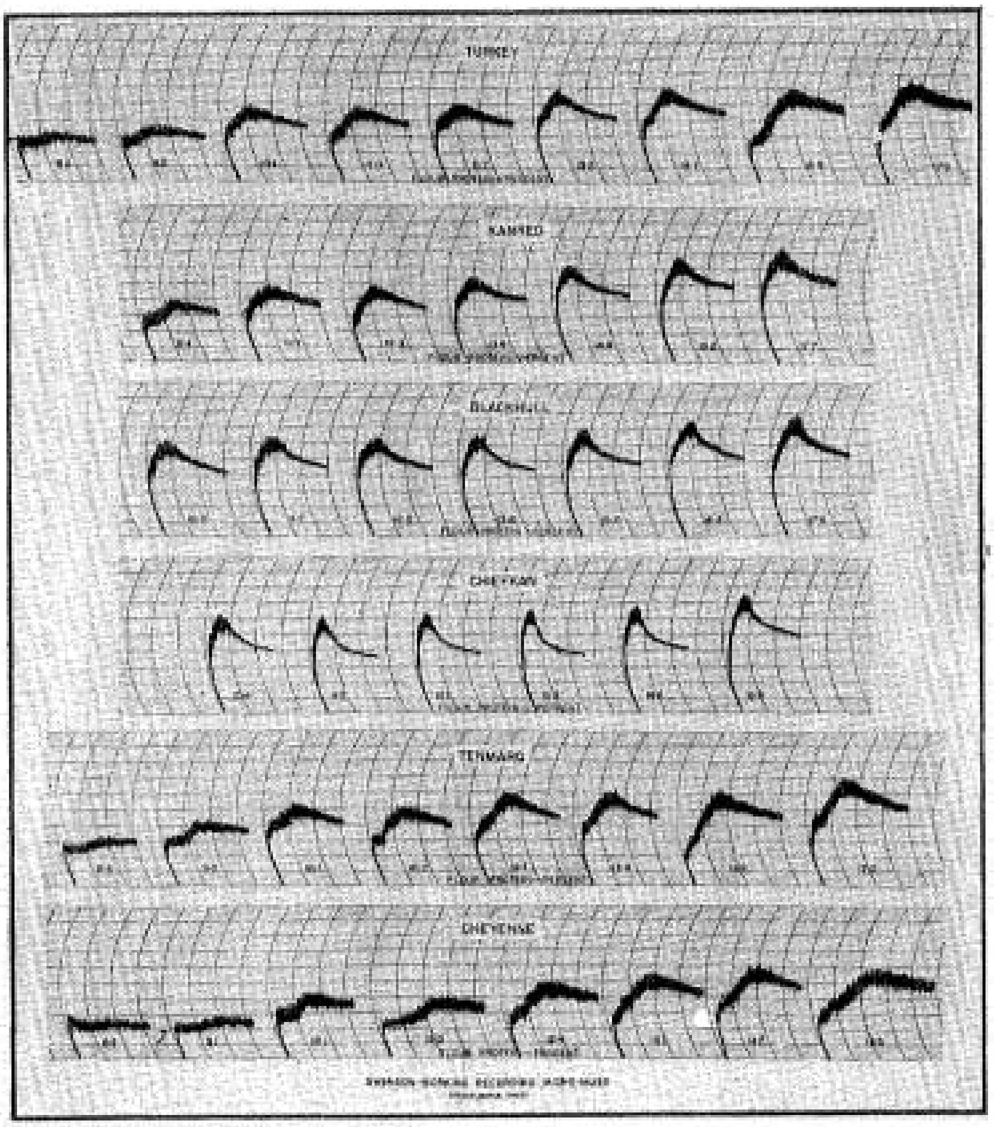


FIG. 3.—Curves obtained on a series of pure line winter wheat varieties at different protein levels with the use of the Swanson-Working recording micro mixer.

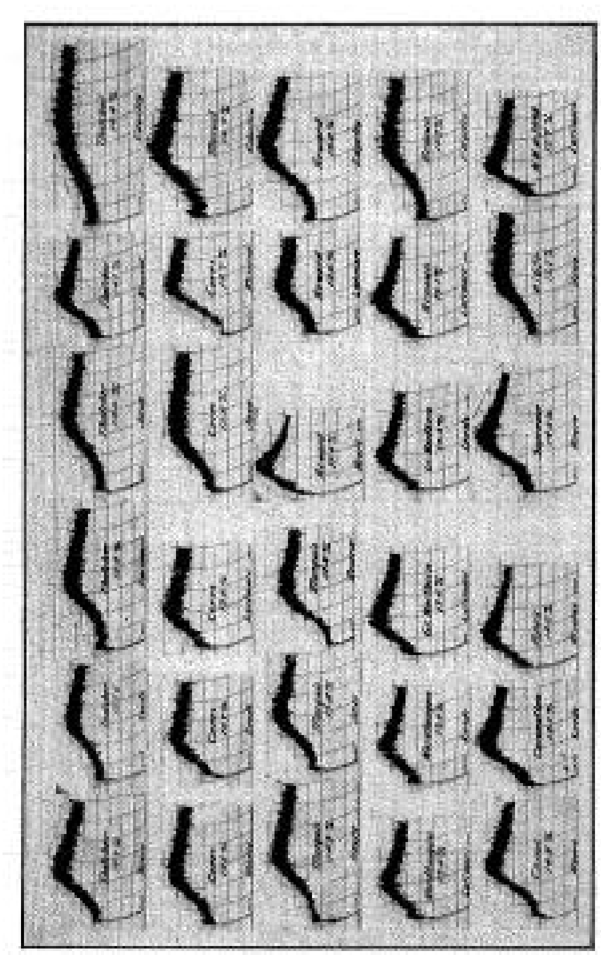


Fig. 4. Curves obtained on a number of well-known spring wheat varieties, using the Swanson-Working recording micro mixer. These curves were not made with exactly the same adjustments of the recording mechanism and hence are not comparable in all respects with those shown in figure 3.

made with well-known hard spring varieties are shown in figure 4. They show that, in a broad sense, the spring wheat flours mix differently from the winter wheat flours, but it can also be seen that some of the high-protein winter wheat samples produced curves little different from some of the spring samples. The most important thing shown by these curves is the magnitude of differentiation between some of the winter wheat varieties. There is probably more difference between the varieties of Chiefkan and Turkey than there is between Turkey and Marquis. On the whole, however, these curves show that the winter wheats are differentiated from the spring wheats by having shorter mixing times.

Other features of these or similar curves have been interpreted in terms of baking performance of the flours. Swanson and Working (1933), Swanson (1936, 1939) and Swanson and Clark (1936) have drawn various conclusions regarding the mixing curves made by means of the Swanson-Working instrument. Principle of these is that the duration of the flat part at the maximum of the curve is an indication of the ability of the flour to endure mechanical treatment in the bakeshop. The rate at which the curve declines in both height and width has also been considered as a probable indication of the stability of the dough during fermentation and machine handling. Recent work indicates that much more work with this instrument is necessary before these features of the curves are fully understood. Meanwhile the curves provide an excellent means for determining to what class or type any given flour belongs. This in turn gives some indication of its handling requirements. Mixing curves thus serve to differentiate flours as to *kind.*

The reader is referred to Table XIII for some "development times" of southwest and northwest flours of the season of 1938.

For more detailed discussions of mixing curves the papers cited above should be consulted.

Reaction to Bleaching and Oxidizing Agents.—It has long been recognized that the hard winter wheat flours require different bleaching treatment than the spring wheat flours. Not a great deal of experimental data on this subject are available. Swanson and Kroeker (1932) reported the results of baking tests made on three hard winter wheat varieties and one spring wheat variety, bleached with various dosages of chlorine. Their results, which are summarized in Table XXVI show that as the dosage of chlorine was increased, the loaf volume of the spring wheat flour decreased progressively, while that of the hard winters tended to increase up to "full bleach" and showed decreased volume only in the case of "double bleached" flour.

The values given for the hard winter wheats are averages of four samples, which had a mean protein content of 11.41 percent as compared to the hard spring sample of 12.95 percent.

The bleaching requirements of the two classes of flour give a rough indication of their reactions to potassium bromate in baking.

TABLE XXVI.—BAKING RESULTS WITH HARD SPRING AND HARD WINTER WHEAT FLOURS TREATED WITH VARIOUS DOSAGES OF CHLORINE. (Swanson and Kroeker, 1932)

BLEACHING TREATMENT.	Spring.			Winter.		
	Loaf volume.	Crumb.		Loaf volume.	Crumb.	
		Texture.	Color.		Texture.	Color.
None	2,100	98	93	2,034	98.5	93
Half	2,060	98	96	2,029	98.2	96
Full	2,020	97	98	2,061	98.0	98
Double	1,940	96	99	1,992	97.5	99

It was shown by Larmour and Machon (1931), using spring wheat flours, that bleaching with chlorine acts in *the same direction* as bromate applied in the baking formula. Chlorine-bleached flours gave, in many instances, bread similar to that, produced with unbleached flours baked with 0.001 percent $KBrO_3$.

It is generally believed that flours bleached with the chlorine-containing bleaching agents require less bromate than they would if they were unbleached. This has sometimes been interpreted as meaning that bromate and chlorine bleaches have the same action. There is no direct evidence to support this view. While they each contribute to produce similar results, they may act in wholly different ways.

The effects of chlorine bleaches and of potassium bromate are frequently referred to as "oxidizing" effects, because these reagents are actually powerful oxidizing agents. However, it is well known that many other powerful oxidizing agents have little effect on the physical properties of gluten. Bromate and chlorine appear to have a specific action, and therefore, it would be less confusing if the term "oxidation of flour" were abandoned, and reference made to "bromate effect" or "chlorine-bleaching effect."

Much research has been done in the attempt to ascertain the reasons for the effects of bromate and chlorine. Discussion of these investigations is beyond the scope of this paper. Suffice it to say that there is little agreement on the subject, and much work remains to be done before this matter can be explained in a satisfactory manner.

It is probable that the use of potassium bromate for loosening up or mellowing the gluten of flours originated with Werner (1925), who had observed that winter wheat flours were greatly improved in loaf volume and texture by the addition of 0.001 percent $KBrO_3$ to the baking formula. Since that time it has become a widespread practice to include this substance in the formula, especially for experimental baking. It is included in various commerical "flour improvers" or "yeast foods."

For a number of years, those working with spring wheat flours were reluctant to believe that bromate contributed materially to the baking results, but in recent years it has been shown to be quite necessary, especially for testing high protein spring wheat flours. Larmour (1931) showed that potassium bromate is necessary in the baking formula when extremely high protein flours are being tested. This conclusion has been confirmed by Aitken and Geddes (1934), Geddes (1937) and many others. Geddes and Larmour (1932) showed that the general optimum dosage of bromate for spring wheat flours is about 0.001 percent. Only in the high-protein flours can higher dosages be used to give increased loaf volume and texture.

Despite the fact that bromate has been considered practically essential in the experimental baking formula by both the southwest and the Canadian chemists, its use has been regarded with considerable scepticism by northwest chemists. Flohil (1936) remarked:

"Why southwestern and Canadian flours as a rule react better to chemical flour improvers than northwestern flours, requires further investigation. The variation in the behavior of these classes of flour may be due either to differences in proteolytic quantity or to differences in the susceptibility of the relative glutens to proteolytic action."

Harris and Sanderson (1937), on the other hand, indicated that the use of potassium bromate in the baking formula with experimentally milled flours contributed materially to the differentiation of their qualities.

An important contribution to this subject was made by Ofelt (1939), who studied the effect on baking results of various increments of $KBrO_3$, using a number of different classes of flour which included both hard spring and hard winter flours. His work showed conclusively that the hard winter flours require higher dosages of bromate than the hard spring flours for optimum baking performance. A comparison of the data presented by Larmour, Working, and Ofelt, (1939) with those of Aitken and Geddes (1934) brings out the curious conclusion that the winter wheat flours seem to vary considerably in their bromate requirement as the protein content increases, while the spring wheat flours exhibit this tendency to a far lesser extent. Thus the spring wheats appear to perform best over the whole protein range with 0.001 percent bromate, while the high-protein winter wheat flours seem to require much heavier dosages than do the lower-protein samples. This is brought out by Ofelt and Larmour (1939).

From these considerations it appears reasonably certain that the hard winter and hard spring flours are qualitatively differentiated in respect to their requirements of potassium bromate. While this can scarcely be considered a *quality* difference, inasmuch as it can be adjusted readily either by the mills or in the bakeshop, it may account for some of the failures to evaluate the winter wheats correctly.

Diastatic Activity.—At present it is generally accepted that the naturally occurring diastatic activity of wheat flours ought not to be regarded as a factor in appraising qulality, because it is a simple matter to adjust this factor in either the mill or the bakeshop. In mills this is done by adding the correct amount of malted wheat flour, and in bakeries either malted wheat flour or diastatic malt syrups are used in the baking formula. It is true that in many European countries where these practices are not followed the naturally occurring diastatic activity is an important factor in determining the baking performance of flours, and in those cases it may be considered a rather important quality factor.

Before the practice of "diastating" flours became common in America, considerable attention was paid to this property of flours. Rumsey (1922) made a study of the diastatic activity of various spring and winter flours, and attempted to show that the baking value was dependent on this factor, provided the relative quality and quantity of the gluten was the same. The baking method used involved a "lean" formula, and consequently the rate at which starch was hydrolyzed to maltose might easily be a limiting factor in CO_2 production during fermentation. His data are given in Table XIV. Although the relationship between specific loaf volume and diastatic activity is not particularly high, there does appear to be some relationship. Rumsey's work was important because it directed the attention of millers and bakers to the wide range of variability that exists in different flours. Although it is not a factor of importance in evaluating quality at present, the determination of the diastatic activity has become a routine procedure in mill laboratories for the purpose of controlling the dosage of malted wheat flour used.

Coleman, Snider, and Dixon (1934) reported diastatic activity values for a number of classes of United States wheats. These average values, given in Table XXVII, show that durum wheat flours are highest, hard red spring next, followed by hard red winter, with soft red winter flours the lowest.

TABLE XXVII.—AVERAGE DIASTATIC ACTIVITY VALUES OF VARIOUS CLASSES OF UNITED STATES WHEAT FLOURS. (Coleman, Snider, and Dixon, 1934)

CLASS.	Number of samples.	Average diastatic activity, Rumsey units.
Durum	25	234
Hard Red Spring	33	227
Hard Red Winter	104	168
Soft Red Winter	33	156

These observations are confirmed by Swanson (1935), who stated:

"The hard spring wheats seem to be higher in activity (diastatic) as a rule than the hard winter wheats."

Landis, Frey and McHugh (1935), in a study of sugar levels in various types of flour, presented data which showed that the spring wheat patent flours were considerably higher in saccharogenic value than the hard winter patents. Their data are reproduced in Table XXVIII.

TABLE XXVIII.—THE RELIABILITY OF SUGAR LEVEL CALCULATIONS. (Landis, Frey and McHugh, 1935)

FLOUR.	Saccharogenic values.				S_r (basic) (calculated)
	p	s	S_a	S_r	
Northwest Patent	4.52	0.83	5.3	3.7	1.7
Southwest Patent	2.50	0.57	7.8	3.3	—0.8
Kansas Hard Winter	2.68	0.43	7.9	3.5	—0.9
Montana Marquis	7.00	1.32	1.7	3.0	5.3
Washington Baart	2.62	1.03	6.8	4.3	0.2
Dicklow	2.42	0.81	7.4	4.1	—0.4
Idaho Hard Winter	3.20	1.21	5.8	4.2	1.2
Western Club	3.52	0.97	6.0	3.4	1.0
Idaho Turkey	3.20	0.79	6.7	4.4	0.3
Western Patent	3.52	1.48	5.0	3.9	2.0

S_a. Added sugar in percent.
p. Primary saccharogenic value.
s. Secondary saccharogenic value.

There seems to be a fairly general agreement in the opinion that hard red winter wheat flours on the average are lower in natural diastatic activity than the spring wheat flours.

Recent investigations have indicated that the diastatic activity of flours may not give as much information as was hitherto thought in regard to the "gassing power" of doughs. Fisher, Halton, and Hines (1938) studied the maltose production in flour and dough of a Manitoba and a hard winter flour, and found that with 2 percent yeast at 80° F. the hard winter flour gassed freely, and at an increasing rate for six hours, while the Manitoba wheat flour did so for only five hours. They concluded that hard winter flour was the better gasser.

Sandstedt, Blish, Mecham, and Bode (1937) consider that the gassing power of flours is dependent upon two types of starch, which they describe as (a) raw starch which constitutes the main portion, (b) a small variable amount of damaged or otherwise readily available starch together with dextrins. The latter fraction is readily hydrolyzed and is probably what is being measured by the usual methods of determining diastatic activity. In addition to different fractions of starch, there also are at least two amylolytic enzymes, and according to the evidence of Blish, Sandstedt, and Mecham

(1937), a "raw starch factor" which appears to be associated with the rate of hydrolysis of raw starch. Further studies by Blish and Sandstedt (1937), and Sandstedt and Blish (1934, 1938, 1939), indicate the presence of biocatalytic substance which influences the rate of fermentation of maltose by bakers' yeast. This substance, designated "Factor M" varies considerably in different flours. As the rate of fermentation appears to be dependent on the activity of this "Factor M," even in the presence of excess sugar, it is evident that in any method of baking, involving fixed fermentation and proofing periods, it could become a quality factor. To date these studies have not been carried out extensively enough to enable one to judge whether or not there is any significant difference on the average between hard spring and hard winter flours, although it has been indicated that Canadian spring flours usually seem to be rich in this activator.

It seems fairly evident that the hard winter and hard spring wheats are differentiated in respect to diastatic activity, which is not an important quality factor. It is probable that they may also be differentiated with respect to fermentation activity, which as far as is known at present would have to be regarded as a quality factor unless certain modifications of the customary baking procedure were applied.

TABLE XXIX.—AVERAGE FLOUR YIELDS AND SOME TEST WEIGHTS OF HARD RED WINTER AND HARD SPRING WHEATS AS REPORTED BY VARIOUS WORKERS

SOURCE OF DATA.	Class of wheat.	Number of samples.	Average flour yield, percent.	Average test weight, pounds.
Stewart and Hirst (1913)	H. R. S. H. R. W.	8 101	66.0 66.9	Not given. Not given.
Thomas (1917)	H. R. S. H. R. W.	555 387	70.2 72.0	60.5 62.1
Bailey (1913)	H. R. S. H. R. W.	14 8	72.8 73.8	Not given. Not given.
Bailey (1914)	H. R. S. H. R. W.	22 22	70.4 70.1	Not given. Not given.
Shollenberger and Clark (1924)	H. R. S. H. R. W.	1,310 728	69.3 72.0	56.9 58.8
Coleman *et al.* (1930)	H. R. S. H. R. W.	28 82	70.4 71.7	58.8 59.9
Swanson (1933)	H. R. S. H. R. W.*	30 77	72.4 71.2	61.2 58.7
Coleman *et al.* (1930) Canadian export cargoes, Grades Nos. 1, 2 and 3.	H. R. S.	110	71.2	61.3

* Average of two years.

Flour Yield.—Flour yield is not a factor in baking quality, but it is important in appraising the milling value of wheats. Most of the comparative data published show that the flour yield is higher for hard winter wheats than for hard spring wheats. Values for flour yield have been included in Tables III to XI, inclusive, and XVI. Some of the more important of these comparisons, together with the data of Thomas (1917), and some unpublished data of Swanson (1933), are given in Table XXIX.

There is abundant evidence to show that flour yield is rather closely related to test weight of the wheat. It should be noted in Table XXIX that in all the instances cited, except for the data of Swanson (1933), the average test weight of the hard red winter wheats was equal to or higher than that of the hard spring wheats. If the flour yield is corrected for these differences in test weight, it appears that the lower average flour yield of the spring wheats is almost exactly proportional to their lower test weights. The computation of flour yield per unit test weight may be criticized, but if one is to get a correct appraisal of the relative milling *qualities* of these two classes of wheat, the difference in their average test weights ought to be taken into account in some manner.

In this connection it is interesting to recall that in most of the comparative baking tests discussed earlier in this paper the average protein content of the winter wheats was lower than that of the spring wheats. This may have been related to their higher test weight.

The most that can be said concerning the relative flour yield of the two classes of wheat is that the hard winter wheats, as they occur, yield a higher percentage of flour than the hard spring wheats, on the average. It seems probable that if they were compared at the same test weights there would be no material difference in their flour yields.

Other Properties.—Under this heading there will be included a number of observations of differences between hard spring and hard winter wheat flours. Many of these factors have received too little attention to justify any extended discussion here. There is no evidence that any of the factors to be mentioned contribute to *intrinsic quality* and, therefore, for the time being, they will be considered merely as *differentiating characteristics* not associated with quality.

A number of studies on wheat flour starches have been reported. Rask and Alsberg (1924) measured the viscosities of pastes prepared from starches of various classes of flour. Some of their data are given in Table XXX. The hard red winter wheat flours were higher than the hard spring wheat flours in this respect. The authors commented that it is probable that correlations may exist between the macaroni-making qualities of flours and viscosities of pastes prepared from their starches. Although definite conclusions could not be drawn on this point they remarked that:

"It is a well-known fact in the trade that the products of durum wheats and Kansas hard winter wheats are particularly adapted for macaroni-making purposes. The high viscosities of the starch pastes of these wheats suggest the possibility that their superior macaroni-making qualities may be due to their starches."

TABLE XXX.—VISCOSITIES OF PASTES MADE FROM WHEAT FLOURS OF VARIOUS CLASSES. (Data of Rask and Alsberg 1924)

CLASS.	Viscosity in centipoises (conc. 5.5 percent).	Viscosity average.
Hard Red Winter	137.5	....
Hard Red Winter	105.5	133.5
Hard Red Spring	124.5	....
Hard Red Spring	105.5	114.0
Durum	132.0	....

Mangels (1934) observed that:

"The starches from winter wheats when subjected to heat treatment show a much greater increase in swelling capacity than starches from hard spring wheat similarly treated. Exposure at 80° or 90° C. gives relatively small changes as compared to exposure at 100°C. Durum starch shows about the same increase in viscosity as the winter wheat starches when exposed to heat."

Smith (1925) compared the viscosities of flour-water suspensions of hard winter and spring wheat flours, both with and without the electrolytes present. His data show that the spring wheat flours had the higher viscosities in both instances, but the relative difference was greater when the electrolytes had been extracted. The flours were of different protein contents, the spring wheat flours being the higher, but even when corrected for protein, the spring wheat flours were higher. Durham (1925), on the other hand, presented data that point to the opposite conclusion. Twelve samples of hard winter wheat flour having average protein content of 12.13 percent gave average viscosity of 168, while two samples of hard red spring wheat flours, having average protein content of 12.76 percent, gave average viscosity of 159.

Holm and Grewe (1930), and Bailey and Le Clerc (1935), present data which indicate that winter wheat flours tend to be lower in ash content than spring wheat flours of corresponding grades.

Teller and Teller (1932) compared the various proteins of bran of spring and hard winter wheats and found that there is no significant difference between the two classes in this property.

Whitcomb and Johnston (1930) reported the results of an investigation of the effects of severe weathering on Marquis and Kanred wheats. They could discover no evidence of differentiation of the two classes in respect to change in test weight, germination, protein, ash, or percentage of vitreous kernels. Both samples appeared to react to severe weathering in about the same manner.

The data of Coleman and Christie (1926), in Table XXXI, show that the hard winter wheat flours were higher in "gasoline color value" than the hard spring flours and varied over a greater range.

TABLE XXXI.—GASOLINE COLOR VALUES OF HARD SPRING AND HARD WINTER WHEAT FLOURS. (Coleman and Christie, 1926)

CLASS.	Number of samples.	Gasoline color value.			
		Average.	Maximum.	Minimum.	Range.
Hard Red Spring	18	1.39	1.55	1.25	.30
Hard Red Winter	22	1.69	2.06	1.44	.62

The bound water and water-absorbing capacity of various grades of flour were studied by Kuhlman and Golossowa (1936). Their data, as given in Table XXXII, indicate that bound water is higher, and water-absorbing capacity lower, for winter wheat flours than for spring wheat flours. This holds for flours of 75, 85, and 96 percent extractions. On the other hand, the data of Fraser and Haley (1932) indicate that neither the amount nor the rate of water absorption of Marquis and Turkey whole wheats is significantly different.

TABLE XXXII.—BOUND WATER AND WATER-ABSORBING CAPACITY OF VARIOUS GRADES OF WHEAT FLOUR. (Kuhlman and Golossowa, 1936)

CLASS OF FLOUR.	Yield of flour, percent.	Bound water.	Water absorbing capacity.
Winter wheat flour	75	46.4	50.0
Winter wheat flour	85	48.4	54.1
Winter wheat flour	96	54.4	62.8
Spring wheat flour	75	44.4	60.2
Spring wheat flour	85	46.4	66.0
Spring wheat flour	96	48.4	64.0

Blish and Bode (1935) studied the catalase activity of hard winter and spring wheat flours, and found that there was considerable difference between them. Thus the values for Kanred, Kharkof, and Blackhull were 32, 35, and 33 mm. respectively, and for Marquis and Ceres, 66 and 78 mm., respectively. The winter wheats averaged 33, and the springs 72. It is not known what significance these values may have in relation to other characteristics of the two classes of wheats.

The data of Heald (1937) present the interesting conclusion that the use of vegetable fats as shortening in the baking formula tends to decrease loaf volume of northwest flours, whereas the loaf volume of southwest flours appears unaffected with fairly high percentages of shortening. On the other hand, neither type of flour appears much affected by increase in amounts of vegetable fat shortening. These results are somewhat at variance with those of Sandstedt and Blish (1939), who found that two percent of shortening (Crisco) in the dough formula increased the loaf volumes of both spring and winter wheat flours. Apparently this merits further investigation.

This summary of differentiating characteristics of hard winter and hard spring wheats, which necessarily has been made as brief as possible, indicates that the two classes are distinctly different in respect to mixing characteristics of the doughs, diastatic activity, catalase activity, ash of flour, color of flour, viscosity of their starches, viscosity of their flour-water suspensions, their bleaching and bromate requirements, the bound water of their flours, and the absorption capacity of the flours. At present there is insufficient evidence that any of these properties is a determining factor in baking *quality,* when quality is limited in its application as indicated in the earlier part of this paper. Future investigations may show that some of these properties ought to be considered as quality factors, but until that occurs they should be regarded merely as means for distinguishing the classes.

To the extent that any of these properties may prejudice the consumer against one or the other class, they may be regarded as quality factors where the term "quality" is used to embrace adaptability to a given system of usage.

GENERAL DISCUSSION OF HARD WINTER AND HARD SPRING WHEATS

In the foregoing pages an attempt has been made to bring together as concisely as consistent with clarity, various data which may be used as a basis for making comparisons of the hard winter and the hard spring classes of wheat. Many of the discussions, perhaps, have been too brief, and doubtlessly some data pertinent to the subject have been omitted. No claim is made that this is an exhaustive review. Particularly in connection with the last section dealing with miscellaneous characteristics, it can be realized that one might expand many of the discussions to much greater length, but this was not deemed advisable in a paper of this nature.

The general opinion of European millers and of many in this country is that the hard red winter wheats, while good in quality, are nevertheless to be regarded as somewhat inferior to the United States and Canadian hard spring wheats. Critical examination of the published investigations show that the experimental data do not support this view. On the contrary, the experimental evidence points to the conclusion that the winter wheats are equal to the hard spring wheats in fundamental quality. It is generally considered a matter for serious thought and further investigation when the deductions from experimental data run contrariwise to long-established convictions of commercial men. These convictions are usually founded on experience and are not to be regarded lightly. They may not always prove correct, but in the majority of instances they are sound.

In attempting to find an explanation of this apparent contradiction a number of facts concerning the production and marketing of these two classes of wheats ought to be pointed out. In the first place the spring wheats in the United States are grown for the most part in a region which is actually the southern portion of the whole spring wheat area of the Great Central Plains. The most troublesome part of this large area in respect to quality is along the northern fringe of the part lying in Canada. That portion lying in the United States, in Montana, the Dakotas and Minnesota, where most of the United States hard spring wheat is grown, is on the whole quite well adapted to the production of high-strength wheats. Moreover, the varieties suitable for the spring wheat area of the northern states are relatively few in number and fairly uniform as to quality characteristics. Most of the wheat produced is shipped from the region and milled outside it. There are few large mills located within this wheat-producing area.

The hard winter wheat region lies wholly within the United States, and on all sides it merges gradually into climatic zones unsuited to produce the hard, "strong" types of bread wheat. Frequently hard wheat varieties are grown under climatic conditions suited to soft wheat production, and soft wheats may be produced within the area that should be growing only hard wheats. As a consequence, there is a relatively greater amount of low-protein hard winter wheats produced than is the case with the hard red spring wheats. This tends to lower the general average of strength of the hard winter wheats.

The mills grinding hard winter wheats are located within the wheat-production area to a much greater extent than in the hard spring wheat region. This provides the opportunity for selection at country points which in turn means that the remainder of the wheat flowing out of the area has been fairly well culled in respect to milling and baking quality. The interior mills have the opportunity to produce excellent, uniform, high strength flour, while the smaller mills operating outside the area and using the wheat that is permitted to flow out, frequently produce hard winter flours of considerably lower strength and uniformity. This and other factors result in a certain amount of heterogeneity in the general class of flours marketed as "hard winters."

These considerations are particularly applicable to export wheats. Usually there is no surplus of hard spring wheats and very little wheat of this class has found its way to Europe in recent years. The wheat exported to Europe, whenever there is export, consists mostly of hard red winter, which has been culled down to a rather low average protein content, as shown by the data in Table II. As the European miller looks to the hard types of American wheats for "boosting power" in his blends with soft European sorts, it is not surprising that he should get an unfavorable opinion of the quality of "Kansas" wheats when they average less than eleven percent protein content. This is an example of including in the term "quality," *adaptability* for a certain purpose, in this instance, blending. The low-protein hard winter wheats are not so much low in intrinsic quality as simply of low strength, and on that account unsuited for use as strong blending wheats.

Lack of uniformity in flours may in a broad sense be regarded as an indication of low quality, because, in general, high quality merchandise is characterized by (1) satisfactory *utility value,* and (2) uniformity of supply. It seems probable that much of the criticism of hard winter wheats which has been based on the belief that they are intrinsically inferior to the spring wheats in quality, may in reality be attributed to their lesser uniformity, and to the low level of protein at which they are all too frequently marketed outside the production area. These factors might easily be responsible for the conviction that the hard red winter wheats have a lower utility value than the hard red spring wheats. But utility value should not be confused with *intrinsic quality.*

Most of the experimental tests designed to appraise quality have in reality measured only *strength,* or at most, *utility value.* The available data show that when the differences in protein levels are taken into consideration the hard red winter wheats are capable of producing as great loaf volume as would be expected of the hard red spring wheats of the same protein content. It is possible that the test methods used have been inadequate properly to assess the baking quality of these classes of wheat, and that future investigations using more suitable technique, may reveal that the established trade opinions concerning the relative qualities of hard red winter and hard red spring wheats are correct.

The hard red winter and hard red spring wheat flours possess a number of distinctive characteristics which serve to differentiate them quite markedly. These properties, if understood, do not interfere with their respective capacities to produce good bread, but they may enter into the appraisal of the utility value of the two classes of flour in a rather important manner because they undoubtedly influence the *specific adaptability* and *preference* factors which are usually taken into account in commercial evaluation of flours. These factors, however, are subject to abrupt changes and are most difficult to appraise because of the variety of methods and the wide range of preferences. Consequently in any scientific study of wheat these factors ought to be segregated as far as possible from the intrinsic quality factor. The latter can be appraised in the laboratory, but the correct evaluation of *utility value* as a whole would require a close study of commercial practices in the grain trade, mills and in bakeries, price fluctuations, consumer demand and many other factors usually considered outside the field of the cereal chemist.

CONCLUSIONS

Although the belief is prevalent in the United States and elsewhere that the hard red spring wheats are superior to the hard red winter wheats in baking quality, a survey of the published work of many scientists who have used both classes of wheat in their studies fails to provide any consistent support for this view. When the two classes are compared on the same protein basis, the hard red winter wheats are found to be quite equal to the hard red spring wheats in intrinsic baking quality.

The higher commercial rating which the hard red spring wheats have received is likely attributable to (1) their higher average protein content, (2) their greater uniformity, and (3) their long established reputation for high quality. Hard red winter wheat reaching the eastern seaboard is usually much below the average of the wheat produced in the Southwest, particularly in respect to protein content, a circumstance which creates a poorer opinion of the whole class than is warranted. This is especially true in the case of European importers who purchase American wheat for blending with weaker sorts. It would be difficult to say to what extent the price of hard winter heat, established on the basis of the exported portions, influences the domestic price, but at least one may say that it has some influence. Thus the poorest part of the hard red winter wheat supply tends to establish the reputation, and to some extent the price of the whole class.

It is evident that the long-time commercial evaluation of wheat must be based on a very broad conception of quality which might be called the *general utility value.* This would include, in addition to baking quality, many other various factors such as uniformity, protein content, specific adaptability, and even personal preferences, factors which, fortunately, are more amenable to change than is the inherent baking quality. Many changes in these factors have occurred since hard winter wheats were first grown in the Southwest, and many more may be expected in the future. How long it will take to establish an unimpeachable reputation for hard red winter wheat depends to a great extent on the efforts of those whose interests are tied up with wheat production in the Southwest.

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