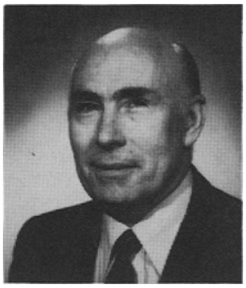

Wheat Gluten as a Protein Ingredient

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ABSTRACT

Wheat gluten is a unique cereal protein due to its property of high elasticity. This elasticity is only present in hydrated gluten, and it is destroyed by heating. The property permits the formation of gas cells in flour dough, and is the essential cause of the texture of our daily bread. Wheat gluten is produced industrially from flour rather than from wheat, although some progress has been made recently in the latter direct process. All the wet separation methods basically involve mixing flour and water and allowing the starch granules to leave the gluten matrix in a mixed aqueous phase. The various methods of wet separation give rise to essentially similar glutens, but the type and severity of the drying process can lead to major changes in degree of elasticity of the reconstituted gluten. In spite of a rather low level of lysine, methionine and tryptophane, the nutritive value of wheat gluten can be high, particularly when mixed with other proteins which supplement these particular amino acids. Although gluten can be used alone, as in some canned vegetarian dishes, generally it is used as an additive to cereal and meat or fish foods. In cereal applications the base material is usually flour or maize, rice or wheat. The market for gluten in the Western World is of the order of 90,000 tons per year, and it is expected that the industrial use of wheat gluten will continue to expand with our technical ability to make use of its unique properties.

INTRODUCTION

Wheat gluten is a protein-lipid-carbohydrate complex formed when flour is hydrated with about an equal weight of water. When the starch is washed away with more water, the gluten coheres as an elastic insoluble rubber-like mass which can be dried to give a cream-colored powder.

Hydrated wheat gluten is unique among cereal proteins due to its property of high elasticity, and it is this property which permits the formation of gas cells in flour dough and gives texture to our daily bread.

Wheat grain consists of the outer protective layers, the skin, the germ located at one end, and the central endosperm. Guten protein, constituting 7-11% of the whole wheat, is fairly uniformly distributed as a matrix throughout a more or less starch endosperm, but at the periphery there is a concentration of gluten protein in the subaleurone layer (Figure 1).

The amount of gluten protein present in different wheats varies widely, and in particular hard American wheats may give 50% greater yield of gluten than a soft English or French wheat. All wheat glutens, however, have the property, not possessed by proteins in other cereals, of showing high elasticity when wet. By high elasticity it is meant a material which can be extended many times its length without breaking. Rubber is, of course, the best example in nature of such elasticity. Basically, while the elastic deformation of many solids like metals involves very small movement of molecules fixed relatively to each other by strong intermolecular forces, in the case of rubber and gluten the structure consists of a coiled molecule in which large deformations are possible with small forces. The molecular configurations underlying this behavior are complex but basically arise from the linear polypeptide structure with some crosslinks, probably of the S-S type, between chains.

This property of elasticity can be easily destroyed by drying, and the mark of a good dried gluten is one that can be reconstituted with water with the elastic property more or less intact. Generally the effects of temperature and moisture content during drying are important, and the effects of these two variables are being investigated in our laboratories. In the extreme cases, freeze drying produces a very good quality gluten which rehydrates perfectly, while a badly overheated gluten results in devital gluten with no elastic properties.

METHODS OF MANUFACTURE

In making gluten industrially from wheat, it is usual to start with a dry flour milling process which largely separates the skin, germ and endosperm of the wheat. Little detailed work has been done on the effect of the milling process on either the quantity or quality of gluten recoverable from the flour, but as a general principle it is preferable to keep the starch damage to as low a level as possible, and some manufacturers use a special simplified milling process.

Gluten is made from flour by one or two basic processes – either the *Martin process* in which a fairly stiff dough is formed and washed with water to remove the starch, or by the *batter process* in which a thin batter is made and then worked and further water added until the gluten fibrils coalesce to give a curd. The *new Raisio process* is a more sophisticated example of the basic batter process. Details of these methods do not concern us here, but when examining samples of glutens for specific applications, it is worth remembering that it can have come from a strong or weak flour, have been formed by the dough or batter process,

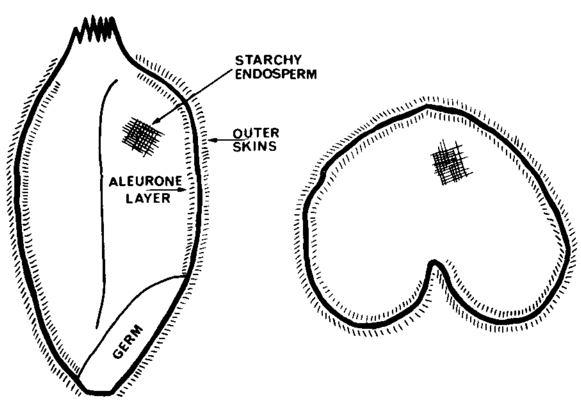

FIG. 1. Parts of the wheat grain.

TABLE I

Typical Amino Acid Profile of Wheat Gluten

Amino acid	Grams of amino acid per 100 grams of protein
Alanine	2.0
Arginine	4.3
Aspartic acid	3.4
Cystine plus cysteine	1.7
Glutamic acid	32.5
Glycine	3.2
Histidine	2.1
[a]Isoleucine	4.2
[a]Leucine	6.9
[a]Lysine	1.6
[a]Methionine	1.7
[a]Phenylalanine	4.9
Proline	11.6
Serine	4.3
[a]*Threonine*	2.4
[a]Tryptophane	1.0
Tyrosine	2.8
[a]Valine	4.3

[a]Essential amino acids.

and been dried in one of a number of designs of drier operating at various temperatures.

Work on recovery of gluten directly from whole wheat by a wet grinding process, particularly the *Farmarco process*, has succeeded in producing good quality gluten, but this has not yet been used in a full scale plant.

The method of drying of wet gluten is critical. Vacuum drying or, better still, freeze drying is satisfactory, but both methods are too slow and expensive for modern industrial plants. If the drying is done at higher temperatures, then it is essential to keep the moisture content low before heating, and in some driers this is achieved by back mixing dry gluten at, say, 8% moisture with wet gluten at 65% moisture to give a mixture at about 20% moisture before subjecting it to hot air. The most common equipment in use today for gluten drying is the Barr and Murphy ring drier in which the wet gluten is injected into the recycling dry gluten as small pellets. This equipment requires careful control but is capable of producing a vital gluten of good quality. In theory the vitality of the gluten could be improved at the expense of output by lowering the air temperature, but in practice this is not easy because too low a rate of drying can cause the gluten to stick on the inner walls of the drier and cause a blockage.

It is customary to grind the finished gluten down to a fine particle size, and some manufactures sieve the product and regrind the oversize particles so that the customer receives a more uniform product.

PROPERTIES OF GLUTEN

In some products, e.g., in starch-reduced breads, the nutritive value and particularly the protein level is very important, but probably in the developed world where most gluten is consumed, the primary reason why manufacturers pay for gluten and incorporate it in their products is that it improves appearance and overall palatability.

However, in the dietary field of body weight control, the use of protein, which satisfies hunger for a longer period than the same weight of carbohydrate, is an accepted aid, and expanded gluten products are a good example of this use of protein.

Reverting to the nutritive value, gluten protein is normally accepted as a similar source of protein to bread. All the essential amino acids are present in gluten, but there are partial deficiencies of lysine, tryptophane and methionine. This is not significant in a normal mixed diet, and gluten can be regarded as a good quality protein for incorporation in foods. As an example, a mixture of 60% soy and 40% gluten has a higher nutritive value than either protein alone. The amino acid composition is normally quoted as shown in Table I

TABLE II

Analysis of Wheat Gluten

	(%)
Moisture	7
Protein (N x 5-7)	71 (as is)
	76 (dry basis)
Fat	6
Mineral	0-8
Carbohydrate	15
Acetic acid solubility	82 (minimum)

The only disadvantage, which should be mentioned for completeness in any consideration of gluten nutrition, is the coeliac problem. There is a small part of the population (about 1 in 2,000 in the U.K.) who are sensitive to the particular proteins present in cereals, and at present the only solution is for such persons to avoid these proteins in their diets. The addition of wheat gluten to products in which the public would not normally expect to find it, like in meat chunks or sausages, does, therefore, introduce a problem. However, as coeliac patients now have expert advice and help this is not a serious difficulty. Wheat gluten has also been shown to have immunological properties in some persons, i.e., gives rise to the formation of antibodies, but the significance of this work is still the subject of research. In testing wheat glutens for food applications, a number of tests are used. Gluten is characterized approximately as shown in Table II.

The more important tests are physical in nature and include particle size, water absorption (140-180%) and speed of hydration (10 to 50 seconds to form an elastic mass in a particular mixer). A skilled observer can also assess a gluten quite well by mixing up a gluten with water by hand and estimating the elastic properties by hand stretching.

Other tests simulate the conditions under which gluten exerts its particular properties. For example, in one of the gluten baking tests 15 g of dry gluten are mixed with 26 g of water, and the slurried wet gluten heated for 25 min. in an oven at 205 C. Volume and texture of the resulting expanded mass are taken as a measure of the performance of the elastic properties of the gluten in both baking and meat chunk applications.

In Germany the Farinograph is used by adding dried gluten to a standard batch of starch and measuring the change in Farinograph height per 1% gluten addition. In France the Alveograph is favored as a testing method, and the improvement resulting from the addition of dried gluten to a standard starch is measured.

Work on the assessment of the bread baking quality of dried gluten is now becoming more sophisticated. I am indebted to Dr. M.R. Booth and Mr. M.F. Timms of the Lord Rank Research Centre for indicating the effect of gluten quantity and quality on loaf volume. These results were obtained with small 2 oz. loaves with a basic bread mix made from a standard flour from which the original gluten had been removed and the resulting starch and water soluble material freeze dried. The test gluten was then incorporated with starch to make flours in which all the protein present was from the gluten under test and a number of loaves baked from flours containing increasing amounts of added gluten. This method of test measures the slope of the line relating loaf volume and protein content and this slope is called the protein response of the gluten (Figure 2). We have examined commercial glutens from all over the world by this method and find wide variations in this property showing either that the different wheats used have affected quality or that some functionality of the

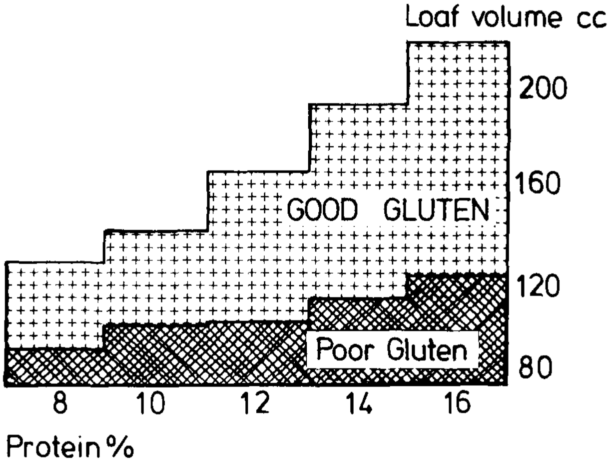

FIG. 2. Bread baking performance of gluten.

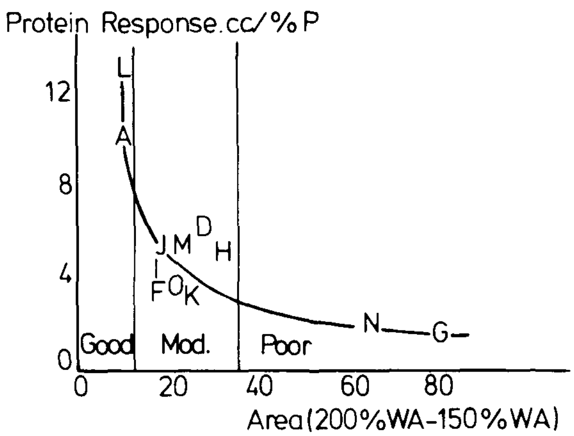

FIG. 3. Gluten bread baking quality and work input to development.

gluten has been lost during processing. This technique is rather time-consuming and a much quicker method which correlates well with the above results is based on the fact that although good and poor quality glutens develop elasticity fairly rapidly at low water additions, at larger additions, the poor gluten takes a much longer time and requires more work to develop. A measure of this difference in development time at 200% and 150% water absorption is found to correlate quite well with the protein response of the gluten, as shown in Figure 3. More details of this work are to be published (1).

USES IN FOOD

Considering more specifically the use of wheat gluten as a protein ingredient in food, the uses can be classified as follows.

1. In the U.K. in particular, gluten is used in starch-reduced, high protein baked goods. In these products the overall protein content is usually ca. 50% and the gluten acts both as a texturizing agent and as a concentrated source of protein without the associated high starch content of normal bread. The density of such products is ca. 0.05 compared with 0.15 for light weight breads and 0.2 for standard U.K. bread. This reduction in density is achieved almost entirely by the incorporation of gluten in the recipe.

2. In the U.K., France and the U.S.A., wheat gluten is used to increase the protein content of bakers' flour by 1 to 5% to improve quality for special applications. In the case of light weight breads and morning goods in the U.K. the use of gluten increases the volume and improves the texture. In specialty breads which often contain significant amounts of special additives like rye flour, milk powder, etc., the addition of gluten restores the volume, fine texture and resilient crumb, which would otherwise be lost by incorporating these additives.

TABLE III

EEC Production of Wheat Gluten

	(Tons per annum)
Belgium/Luxembourg	2,000
France	4,000
West Germany	10,000
Italy	2,000
The Netherlands	4,000
U.K.	3,500
Ireland	500
	26,000

3. The general problem of fortifying weak European bread flour with gluten instead of using large amounts of expensive, imported strong wheats is a complicated one, and depends to come extent on economics and on the type of bread required. In the U.K. the popular loaf is usually made by the rapid Chorleywood process, and is a light moist loaf of good slicing properties which keeps very well. In this application color and water absorption are important as well as loaf volume and texture. In France where long fermentation bread is the rule, the color and water absorption are much less important, and the use of gluten in bread flour is becoming widespread. The quantitative effects of gluten will vary with the recipe and method, but recently Benson (2) has reported that a 1% addition of wheat gluten will generally increase final loaf volume by 3 to 5%, that 2% gluten addition will improve tolerance to mixing variations by 25%, and that 2-3% addition will increase bread softness to give a softer loaf after four days than will occur with three days without the gluten addition. In recent years the use of gluten to increase loaf volume has received competition from emulsifiers, but some manufacturers have tried to obtain the best of both materials by selling a mixture of gluten and emulsifier.

4. In countries where cereals do not grow well, gluten has also been used in conjunction with root crop starches like cassava to produce flours suitable for bread making. There has been some application of this method in South America.

5. One rather specialized bakery application is in improving the elasticity of the hinge in cut rolls used for hamburgers. I do not know of any reported quantitative work on this phenomenon, but it is widely reported that this application accounts for significant amounts of gluten in the U.S.A.

6. In breakfast cereals wheat gluten again has two uses. Functionally it may help in giving more strength to some extruded and flaked materials, while in products making nutritive claims it is also used to raise the protein content of the product.

7. In pastas there is a similar distinction between these two functions of gluten, although as far as I know, high protein pastas have not been as successful as breakfast cereals in capturing a significant share of the market.

8. Although this paper is primarily concerned with the bakery and snack field, for completeness the use of gluten in meat analogs should be mentioned, since this use accounts for perhaps 25% of the total gluten produced. Again, the primary contribution made by gluten is in imparting physical properties, and many manufacturers have succeeded in obtaining a meat-like texture from gluten either alone or with soy material (as in

vegetarian dishes) or with meat offals as in meat chunks or petfoods. In Japan there is a similar texturizing application in which gluten is combined with fish to make a variety of processed foods.

9. There have been proposals to use gluten in various novel applications involving its film-forming property such as in processed meat casings, and also in various chemical modifications which impart special properties like high water absorption. However, in spite of much effort, there has been little market development arising from these applications

The market for gluten in the Western World is of the order of 90,000 tons per year, of which perhaps 50,000 is consumed in the U.S.A. and 10-12,000 in the U.K. The pattern of production is changing due to new plants planned or coming on stream in the U.S.A., but it is of interest that currently only about half the U.S.A. demand and only about one-third of the U.K. demand is met by their domestic production. The introduction of tariff barriers by the EEC has made it much more difficult for gluten from traditional Australian suppliers to enter European countries. Current EEC production is shown in Table III.

Demand for wheat gluten can be expected to rise gradually as the market for dietetic foods and for lighter textured breads grows in the more affluent countries. Politically the EEC is likely to encourage use of its surplus wheat as a source of starch, and this necessarily involves the production of wheat gluten on an increasing scale. It is possible that some major new use for gluten will be developed and will add to the present demand, but even if this does not happen, the growth in current uses should keep the industry busy in the foreseeable future.

REFERENCES

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