Nutritional and processing quality in barley and oats for food - a review.

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Abstract

Barley and oats have been identified recently as having fibre types that are of particular value for human health, and are thus enjoying a renewal of interest as foodstuffs. This paper briefly discusses the role of these fibres and their relationship to other fibres in the reduction of blood cholesterol levels, risk of colorectal cancer, and control of diabetes and appetite.

Plant breeding has traditionally increased the starch content of barley and oat grains at the expense of other polysaccharides. This paper outlines the breeding initiatives being taken to reverse this trend, including screening of normal barley and oats for high fibre lines, and the use of related species to donate high fibre genes.

Recent studies have revealed new insights about the influence of the environment on the concentration and yield of these fibres in barley and oats. Data are presented to show that high fibre contents can be achieved at high grain yields, and a possible mechanism for controlling fibre synthesis is discussed.

The ratio of amylose to amylopectin in starch (waxiness) has a strong influence on processing properties. This ratio varies significantly in barley. In combination with high fibre content, this opens the prospect of some exciting new food products from barley and oats.

Additional key words: *fibre, cholesterol, health*

Introduction

Historically, barley and oats were important human foodstuffs, in addition to their role as animal feeds, and in the case of barley, as a raw material for brewing. For wheat, various factors, including relatively poor adaptability, the value placed on white leavened bread, and the cost of producing white flour, meant that wheaten products were expensive and often reserved for the ruling classes. However, increasing affluence and urbanisation after the Industrial Revolution meant that a greater proportion of the community could aspire to white bread, and oaten and barley products were considered to be peasant or animal food.

By 1900, human consumption of barley and oats was restricted to agricultural labouring classes of Continental Europe and some Asian countries where wheat production was impossible. The exception, of course, was the morning plate of porridge enjoyed in every Edwardian household of means. In retrospect, it was probably this habit that saved the entire leadership class of Western society from extinction by coronary explosion and terminal constipation. Fortunately, the stigma of eating peasant food has now gone, and barley and oats can be promoted as part of a healthy diet.

Health Benefits of Oats and Barley

Awareness that there are health benefits to be obtained from eating barley and oats is a recent phenomenon. Anderson (1991) summarised a number of studies where oats and other sources of soluble fibre were used to influence human blood cholesterol levels, concluding that consumption of heroic quantities of oat bran did lead to reduction of blood cholesterol levels in subjects where these were above the desirable range. Ripsin *et al.* (1991) reported a meta-analysis in which they re-analysed the raw data from nine studies meeting their criteria for reliability. From this analysis, they concluded that consumption of oat bran equivalent to two breakfasts would lead to a significant reduction in blood cholesterol level in subjects with problems, and that the greater the problem, the greater the benefit.

The work of Newman and co-workers (e.g., Newman *et al.*, 1992) has demonstrated similar benefits from barley flour. Their work focused on hypercholesterolæmia, reflecting the major thrust of the studies with oat bran. However, work such as that of Wood (1991), showing the effect of oat bran in reducing the rate of increase of blood glucose levels after food has not yet been carried out for barley. For diabetics, of course, this suppression of "post-prandial hyperglycaemia" is very important.

Definition of Soluble Fibre

The effects already discussed have been correlated with the non-starch polysaccharide content of the oat bran or barley flour, or more specifically, the "soluble fibre" content. Soluble fibre is defined as the soluble portion of the polysaccharide that is not digested in the stomach and small intestine of the (monogastric) animal under study. In barley and oats, the only significant non-starch polysaccharide conforming to this definition is ß-glucan. ß-glucan, like other materials found to lower blood cholesterol, induces viscosity in its solutions. This viscosity is presumed either to be important *per se*, or to indicate an important molecular property responsible for lowering blood cholesterol level.

A crucial problem yet to be resolved concerns the conditions under which the soluble fibre is extracted. Traditionally, ß-glucan has been a problem for maltsters and brewers (Morgan, 1977; Coles, 1991), and the standard methods for measurement in barley and malt were devised with their requirements in mind. In malting and brewing, pH remains above 5, whereas during digestion there is a low pH phase in the stomach. The flow injection analysis method (Jørgensen and Åstrup, 1988) has a reduced pH step, and generally leads to higher estimates than malting-oriented enzymatic methods (Fig. 1). This figure indicates that the relationship between the two methods is poor. However, this particular set of material is of unusual origin, being derived from interspecific hybrids between *Hordeum vulgare* and *H. bulbosum*. Generally, results from the two methods are better correlated (Jørgensen and Åstrup, 1988; Lim *et al.*, 1992), because the experimental data sets consist of material of very similar origin. Since we are working with breeding material from many sources, we have decided to rely on the FIA method.

Food Barley and Oat Breeding

Selection of barley and oats for improved traits has been going on for at least 9,000 years (Coles, 1983), resulting in increased seed size, largely through increased accumulation of starch. However, these species still have substantial variation in ß-glucan content. In barley, a recent rainshelter experiment, in which crop water was fully controlled, showed that Triumph barley is capable of a twofold variation in ß-glucan content (Coles *et al.*, op.cit.). In oats, considerable environmental variation also occurs (Saastamoinin *et al.*, 1992). For production

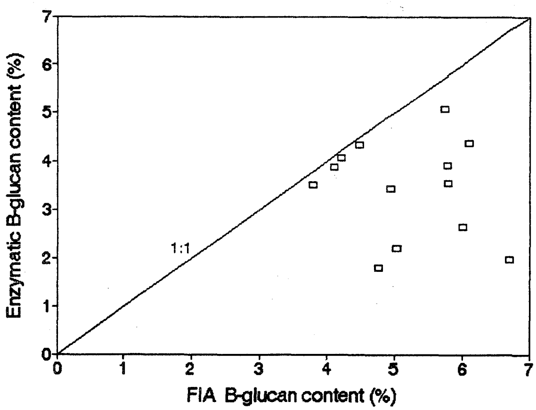

Figure 1. Comparison of enzymatic and flow injection analysis methods for estimating β-glucan content (regression r^2=.03).

this variation is valuable, because within a cultivar, ß-glucan content appears to be positively correlated with yield. There is significant genotypic variation as well, with some barleys capable of producing up to 10.5% ß-glucan, compared with a maximum of 6.0% for Triumph. Similarly, New Zealand oat cultivars, compared in the same trial, can vary between 4.0 and 8.0% (unpublished data).

In view of the fact that selection pressure in barley and oat breeding has historically been for increased starch content, and thus reduction of ß-glucan content, it is likely that a worthwhile initial gain can be made quite readily. Thereafter, several opportunities for novel breeding methods are possible. One possibility is inter-specific hybridisation. Pickering (1992) demonstrated transfer of genes from *Hordeum bulbosum* to *H. vulgare*, so interspecific hybridisation is a reality for this species. *H. spontaneum* also crosses with *H. vulgare*, so this species is also a potential source for increased ß-glucan content in cultivated barley.

To date, there have been no reports of transformation in barley or oats. However, several programmes are actively working with these cereals and, given the recent successes with some other closely related species, hopefully transformation in barley and oats is not far off. It is likely that the first attempts will be made to transfer new genes for simple characters such as herbicide resistance. Increased ß-glucan content is further off and will involve altering the control of the biosynthesis pathway - either the allocation of assimilate to the starch or ß-glucan fractions, or the time of availability of primers for synthesis.

Waxy Starch

Barley and oats were first developed as food products because of their content of viscous soluble fibre, but the ability of barley to produce starches of different types has also been useful. Unlike wheat, barley can produce starch without amylose - so-called waxy starch. Such starches are also found in maize and rice, and confer different processing properties on whole grains and flour relative to non-waxy types. Pasting behaviour is quite different, and puffing and popping occur under more convenient conditions. Results obtained at Crop & Food Research show that this variation is strictly under genetic control. However, it does appear that starches with similar amylose/amylopectin ratios have different solubility characteristics. Further work will be undertaken to investigate this phenomenon. To date, all cultivars identified with waxy starch also have high ß-glucan content, with one exception. Interestingly, the ß-glucan of these waxy types appears to have higher specific viscosity than that from normal cultivars (Rossnagel, pers. comm.).

Food Barley and Oat Production

As noted above, ß-glucan content appears to be positively correlated with yield (Coles *et al.*, op. cit.; Saastamoinin *et al.*, op. cit.). For barley at least, it seems that final ß-glucan content is a good integrator of transpiration during the life of the crop. However, it should be noted that the cultivars on which these observations are based have all been bred for low ß-glucan content, and it is not certain that this behaviour will be exhibited by lines bred for high ß-glucan content. Some results from growth chambers suggest that under cool growing conditions, this relationship also fails (Coles, 1979). Under Swedish conditions, (Gohl, 1977), there is some reduction of barley ß-glucan content between cutting and threshing if the crop is swathed. This aside, good quality product should come from well-managed, well-irrigated barley crops grown in Canterbury, where conditions for crop development, maturation and harvest are generally favourable. Crop & Food Research results suggest that oat bran meeting the international standard of <50% of the grain, 16.5% total fibre and 5.5% soluble fibre can be produced easily in high-yielding situations in Southland with the cultivar "Otama" (Charisma). This line has achieved 8% groat ß-glucan content in Southland and similar levels from autumn sowing in Canterbury (unpublished data).

Insoluble Fibre

For general well-being of the large intestine, an adequate (>20 g) daily intake of insoluble fibre is vital. Wheat bran has long been the most common source for this insoluble fibre. However, recent studies in Australia indicate that barley and oat insoluble fibres are more effective than those from wheat in preventing disorders of the large intestine. These results will require substantial effort to be confirmed.

Recent research (Leeds, pers. comm.) indicates that consumption of cereal fibres, whether soluble or insoluble, can have an important effect on the satiety of subjects in the medium term (3-5 hours after a meal). It is assumed that the fibre constitutes a "slow release" source of calories once it reaches the large intestine and begins to be fermented. The direct contribution to the individual's energy balance is negligible, but the reduction in hunger is a significant contribution to well-being. This is the basis for the finding that breakfast is important during dieting for weight control.

Conclusions.

Consumption of foods high in soluble and insoluble fibre, based on barley or oats, has beneficial effects by reducing post-prandial hyperglycaemia, reducing hypercholesterolæmia in affected individuals, increasing medium term satiety, and improving the health of the large intestine. There are advantages to the food processor in manufacturing products based on barley and oats, since they are readily accepted diet components, the active ingredients are relatively benign in their effects, and they are relatively easily defined and measured. These advantages for public health and for the food marketer have been recognised, and form the basis of a joint development partnership linking industry and Crop & Food Research. This partnership is undertaking plant breeding, agronomic research, food product development and market research, mode-of-action studies and fundamental investigations into regulation of ß-glucan synthesis.

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