# Choice, selection and changes in grain storage carbohydrates in barley

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## Abstract

Human selection of grains for palatability and harvestability may be associated with affects on seed physiology. Two barley types, a landrace selection (Hiproly) and a modern cultivar (Minerva) were grown in a glasshouse. Seeds were harvested from 10 days after anthesis, and then every 4 days, up to 42 days after anthesis. Grain weight, starch, and two non-starch polysaccharides (NSP) (arabinoxylan and β-glucan) were measured for each harvest. Accumulation patterns in the two barley types were similar until day 26 for grain weight, starch, and arabinoxylan and day 30 for β-glucan. After this period, however, Hiproly plateaued while further increases occurred in the modern cultivar, Minerva. This suggested that components could be manipulated by breeding. Also, the accumulation pattern for β-glucan was different from that of the other compounds measured. These changes in seed physiology may have implications for value of the grain for human food and monogastric livestock feed.

## Introduction

The development of agriculture is the ultimate example of human selection of food: its origin is the subject of much debate, from which 3 hypotheses have developed (Meyers, 1971).

1. The process was a natural progression of settling in and mastering the environment, i.e., the development of agriculture was just a coincidence of the cultures of ancient peoples maturing and mastering their surroundings.
2. Agriculture came about because of changes in demographics, i.e., internal and external stresses from population growth and emigration respectively, which changed the food supply available.
3. Agriculture came about due to positive and negative feedback systems which promoted equilibrium between humans and their environment. Positive feedback could be planting and harvesting a crop, while negative feedback would be to hunt the rabbits that eat certain plants: as the rabbit population decreases the edible plant population increases, so humans switch to new diets.

As these varied hypotheses indicate, it is difficult to determine the exact origins of agriculture and the beginnings of large scale selections and plant breeding. However each hypothesis shows that human choice can affect future food resource availability, based initially on what is palatable and harvestable. Our choices may have had additional consequences. Humans have selected cereals to the extent of changing the agronomic characteristics of the crop from one which is beneficial to itself to one that is beneficial for human economy; these new agronomic characteristics have created a co-dependency between cereals and humans. Today, selection has increased yields to produce sufficient wheat, rice, maize and barley to allow reliance on them by humans and their livestock as dietary staples. For example, the yield of New Zealand barley increased from 1.4 t/ha to 3.5 t/ha between 1875 and 1980 (Coles, 1983). The world's population is estimated to increase from 5 to 7.5 billion by the year 2020. Increased yield is required to support that population growth and conserve land resources.

However, in selection for increased yield, physiological changes may have occurred. These changes may lead to cultivars that are not viable, which could have serious implications for us and our livestock.

Therefore, this preliminary study was designed to observe the physiology of the accumulation of two non-starch polysaccharides (NSP): 1,3 1,4 β-D glucan (β-glucan) and arabinoxylan (AX) during seed development. These compounds were selected for measurement because, despite efforts to select varieties with characteristics more desirable to the human palate, these compounds have continued to accumulate in various quantities even though their effects on human and monogastric livestock digestion, and in brewing are not favourable.

Accumulation patterns of starch and NSP in two cultivars of barley, a land race selection (Hiproly) and a modern cultivar (Minerva) with different agronomic characteristics, were examined. This also provided a comparison between two cultivars which differed historically in their selection and breeding.

## Materials and Methods

Two barley cultivars, Hiproly (land race selection) and Minerva (modern cultivar) were glasshouse grown using a standard soil and fertiliser mixture. Overhead natural light was used. Plants were watered to avoid moisture stress. Harvesting started at 10 days after anthesis and then continued every 4 days up to 42 days post anthesis. Sufficient material was gathered to yield approximately 2.0 g of dry matter per treatment at each harvest period.

Free sugar and starch contents were determined using liquid chromatography (Shetty *et al.*, 1974), using an AMINO 220 × 4.6 mm separating column and AMINO 15 × 3.2 mm guard column (Applied Biosystems Brownlee NewGuard) set to 30°C with a column heater (Waters, Milford MA, USA). 100 mg samples of barley flour were used for analysis.

β-glucan was measured using Flow Injection Analysis (FIA) (Aastrup and Jørgensen, 1988).

Arabinoxylans were determined using the method outlined by Douglas (1981), modified to use 50 mg of barley flour. Standard curves were prepared for both arabinose and xylose. Arabinoxylans were determined for each stage of kernel development from 10 days after anthesis to 42 days and maturity.

Results shown were fitted to a logistic curve where appropriate. Curve fitting was done to emphasize trends in accumulation patterns. Statistical analysis was carried out using GenStat 5, Release 3.

## Results and Discussion

Hiproly had an earlier onset of dry matter accumulation but did not fill the kernel to the extent of Minerva (Fig. 1). Minerva may have had a heavier seed due to its being bred recently with emphasis on agronomic yield and seed weight. Seed weight gave an indication of the timing of the accumulation of NSP. The chief polysaccharide accumulated was starch. Hiproly started to accumulate starch earlier and for a shorter period than Minerva (Fig. 2). This may relate to its sink capacity, implying that Minerva has a higher number of endosperm cells or has a more efficient mechanism to fill its cells (Renwick and Duffus, 1987). Starch accumulation followed a similar pattern to total dry matter accumulation. Hiproly accumulated less starch than Minerva.

Hiproly accumulated less AX than Minerva (Fig. 3) reaching its maximum at about 34 days after anthesis, whereas Minerva reached an accumulation plateau at 38 days after anthesis. The rate of accumulation for each type was similar.

Small amounts of β-glucan were present 10 days after anthesis. Hiproly reached its maximum 30 days after

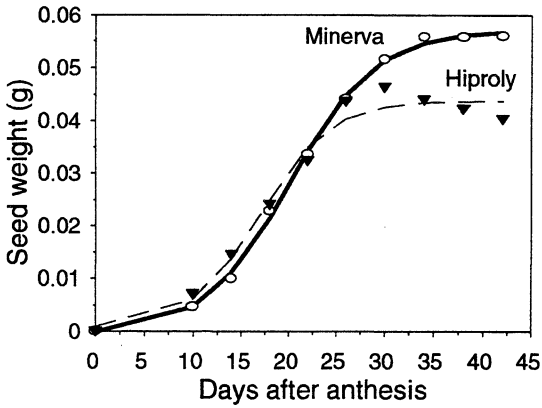


**Figure 1. Mean seed weight (dry matter accumulation) per seed (g) for two cultivars of barley.**

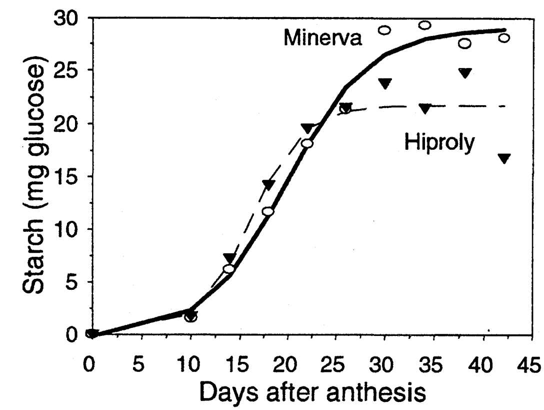


**Figure 2. Pattern of mean starch accumulation per seed (mg) for two cultivars of barley.**

anthesis, while Minerva showed a marked increase in β-glucan content 34 days after anthesis (Fig. 4). This indicated that β-glucan was being used for a purpose other than structural support of endosperm cell walls. In each type of barley the maximum accumulation was followed by a decrease in kernel content of β- glucan.

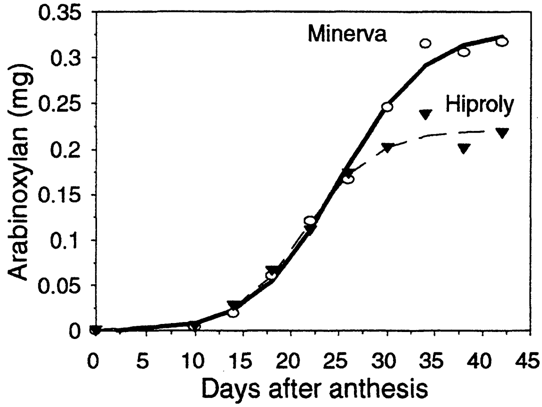


**Figure 3. Pattern of arabinoxylan (total pentosan) accumulation per seed (mg) for two cultivars of barley.**

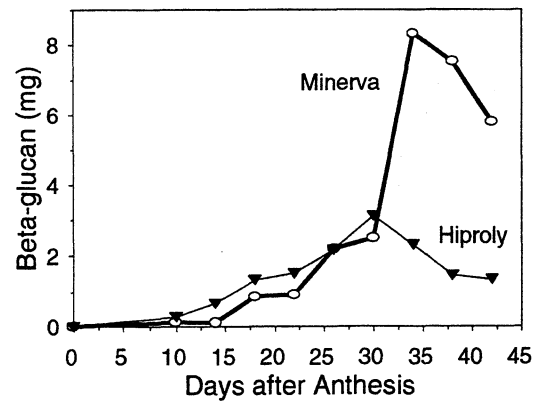


**Figure 4. Pattern of 1,3 1,4 β-D glucan accumulation per seed (mg) for two cultivars of barley.**

## Implications

Dry matter, starch, AX and β-glucan accumulation were greater in Minerva which confirms that agronomi c selection for increased grain weight and starch yield can affect seed filling character and biochemical composition.

These NSPs have been associated with affecting the quality of human and monogastric livestock nutrition. β-glucan reduces malt yield and processing efficiency for the malting and brewing industries and it causes poor growth via maldigestion in monogastric livestock (Bamforth, 1982). β-glucan has also been implicated in reduced incidence of various cancers, heart disease and metabolic disorders (Kahlon and Chow, 1997). Therefore food processors would like to develop an understanding of how these substances effect human physiology, and develop methods for increasing their concentration in the grain, extraction from the seed, and application as a natural ingredient that has health benefits. Arabinoxylans have also been implicated in decreasing beer and bread quality, and in maldigestion in monogastric livestock. However this compound is bound to a ferulic acid (Ahluwalia and Fry, 1986), which acts as an antioxidant and may be beneficial in promoting human health.

These data suggest that human selection has had an impact on the physiology of the barley kernel. These changes have affected the nutritional quality of the grain for human and animal consumption by modifying the NSP content. It may be possible to use modern breeding technologies to further manipulate the content of NSP in the grain for human economic benefit. Work is in progress to cross barley varieties showing high levels or NSP with those that have rapid rates of dry matter accumulation and NSP accumulation, in the hope this will produce types with a combination of each of these characteristics.

The challenge is to understand how these physiological changes occurred with respect to agronomic characteristics of the barley and to manipulate these compounds to meet consumer demand for foods with the desired composition.

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