Barley Starch. V. A Comparison of the Properties of Waxy Compana Barley Starch with the Starches of its Parents[1]

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ABSTRACT

Waxy Compana barley has been developed by the introduction of the waxy gene from waxy Oderbrucker. The physical properties of the starch from the parents, normal Oderbrucker and the derived waxy Compana, have been investigated. Waxy Compana has a higher viscosity than waxy Oderbrucker; this may be associated with the gene responsible for the higher viscosity of Compana in the normal varieties. Although the Brabender cooking curve is nearly identical to that reported for waxy sorghum, the barley starch has only half the swelling power and one third the solubility of waxy sorghum. This suggests that the amylopectin is unique in waxy Compana starch. This might be explained if its amylopectin contains either unusually long branches or natural cross-linking.

Since it has been reported that amylopectin is more readily digested than amylose (1,2) it was considered desirable to introduce it into one of Montana's commercial feed barley varieties. In addition to feed, such a variety would provide the possibility of a new source of raw material for the production of waxy starch.

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[1]Contribution of the Montana Agricultural Experiment Station, Journal Series No. 391.

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Previous work (3) has demonstrated that different varieties of barley produce starch with somewhat different physical properties. The present investigation was designed to determine what changes occur in the starch as a result of genetic change by comparing the starch properties of the parents and the original barley with the newly derived waxy type.

MATERIALS AND METHODS

Preparation of Starches

Waxy Compana barley was developed by introducing the waxy gene from waxy Oderbrucker and back-crossing seven times with Compana. Starch was isolated from the derived waxy Compana, the original Compana, the waxy Oderbrucker, and, for comparative purposes, from the normal Oderbrucker. The grain was steeped 24 hr. with 0.2% potassium metabisulfite as suggested by Watson (4), and the starch separated by the usual wet-milling technique. All samples were screened through 400-mesh screen and centrifuged in a solid basket. The thin dark layer at the top of the basket was removed with a spatula, and the balance air-dried in a current of warm dry air at room temperature.

Determinations

Protein content was determined by the Kjeldahl method (5) (conversion factor 6.25). The samples were ashed according to the usual procedure (5). The total free fat was determined by ether extraction (5). Brabender viscosity was determined with the procedure described by Smith (6). Solubility and swelling power were determined according to Leach et al. (7). Iodine affinity was determined by the technique of Schoch (8) modified by use of DMSO as solvent. Enzyme susceptibility was measured by the technique of Goering and Brelsford (9).

RESULTS AND DISCUSSION

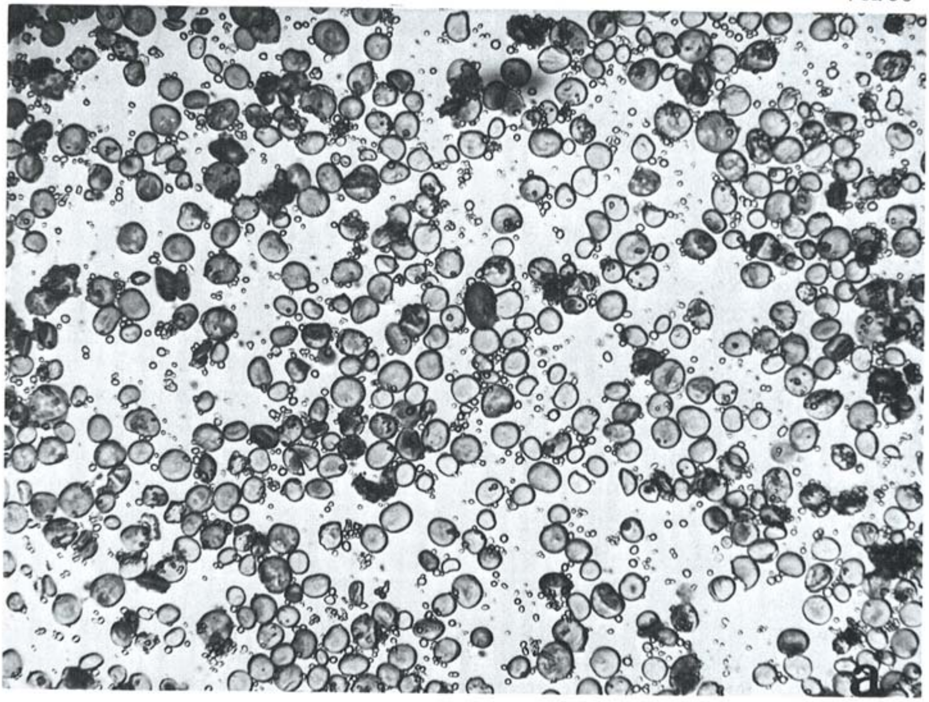
Although all data collected on barley starch granules in our laboratory to date have failed to show significant differences in size or shape, we do have some indications that there are distinct differences in the ratio of small to large granules. Figure 1 shows photomicrographs of the normal and waxy starch.

There is no substantial difference in the appearance of the waxy and normal barley starch at the low magnification, although the size distribution is somewhat greater than is observed for corn. At the higher magnification, waxy barley starch granules appear to show fractures which might account for their susceptibility to enzyme action. Furthermore, the waxy barleys show a floury structure in contrast to the angular granules in maize.

The chemical composition of the barley starches used in this investigation is given in Table I.

The iodine affinites of the waxy starches suggest that either they contain some contaminating amylose or that the amylopectin branches are very long, since Banks et al. (10) have shown that the iodine binding of amylopectin does increase as the chains become longer. The low fat content of the waxy Oderbrucker was unexpected, although occasionally we find a barley starch with a low fat content (3).

The cooking curves are shown in Fig. 2.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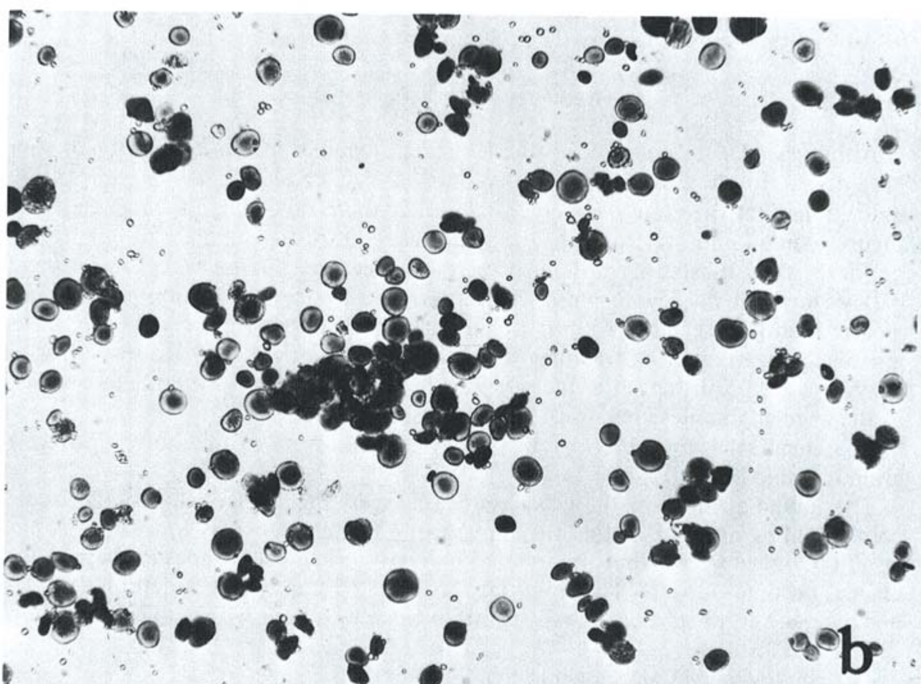
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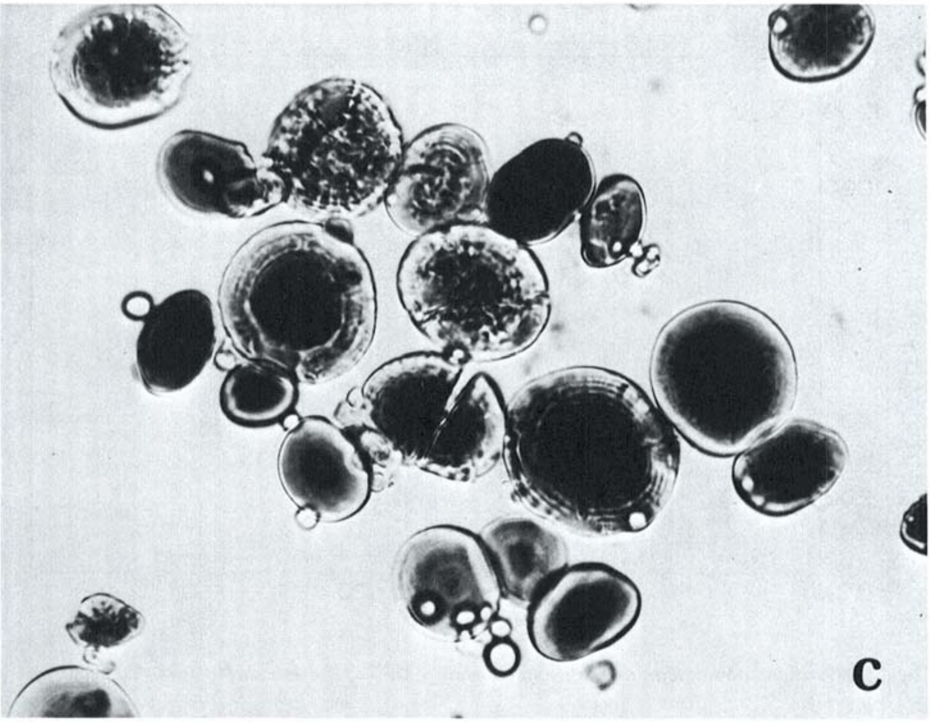

Fig. 1. Photomicrographs of barley starches: a) (facing page, top) Compana, 100X; b) (facing page, bottom) waxy Compana, 100X; c) (above) waxy Compana, 800X.

The Brabender cooking curve for waxy Compana starch is typical of a waxy starch showing very high pasting peak, granule instability and very little setback on cooling. At the same concentration this curve is nearly identical to that shown by Leach (11, p. 301) for waxy sorghum. The waxy Oderbrucker has a much lower pasting peak. This might be expected if it contained substantially more amylose. The small difference in iodine affinity between these waxy starches, in our opinion, is not adequate to explain these differences. Certainly the solubility of the starch pastes shown in Fig. 4 does not indicate a higher amylose content in the waxy Oderbrucker. Another factor, however, might be involved. Examination of the nonwaxy curves indicates that Compana consistently shows a higher viscosity

TABLE I. CHEMICAL COMPOSITION OF BARLEY STARCHES

Starch Variety	Ash %	Fat %	Protein %	Iodine Affinity %
Compana	0.21	0.29	0.30	5.7
Oderbrucker	0.27	0.35	0.33	5.4
Waxy Compana	0.19	0.27	0.31	0.35
Waxy Oderbrucker	0.17	0.06	0.31	0.70

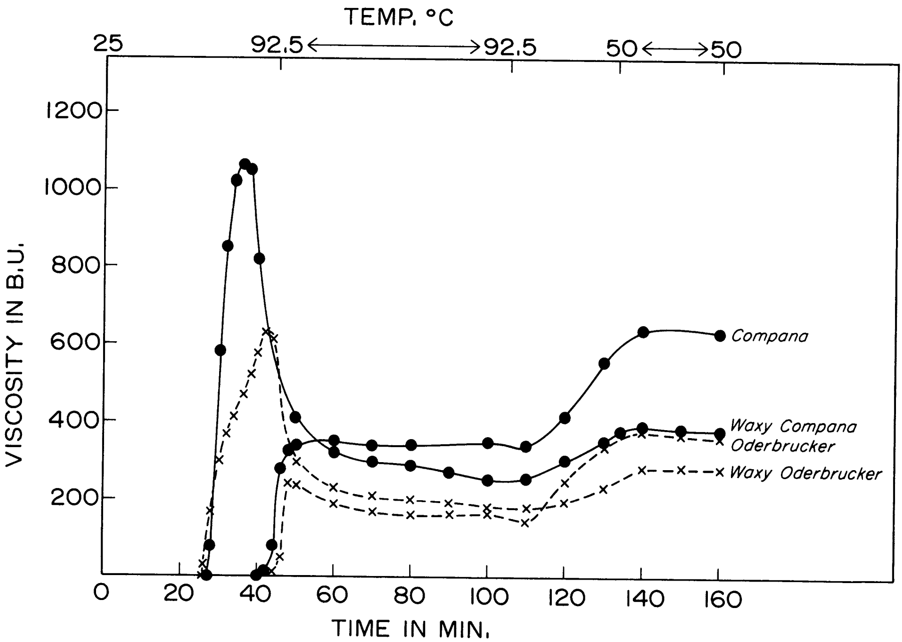

Fig. 2. Brabender amylograms on barley starches from the regular and waxy types (8% level).

throughout the cooking cycle than does Oderbrucker. This might be the result of starch fractions of larger molecular size in Compana, since it has been demonstrated that in another barley derived from Compana (12) the starch fractions were large and that this was associated with higher Brabender viscosities. It is therefore possible that amylopectin in waxy Compana is appreciably larger than that for waxy Oderbrucker, which might account for the observed differences. A study is now underway in our laboratories to determine the validity of this assumption.

Moreover, the pasting temperatures are nearly 20°C. lower in the waxy than in the normal barley starches. Although it has been reported (11, p. 292; 13) that the amylose content of corn and sorghum does not influence the gelatinization temperature of these starches since the waxy has the same or higher gelatinization temperature than their nonwaxy counterparts, this certainly does not appear to be true in the case of barley starch.

The waxy starches are easily broken down by bacterial α-amylase and show almost complete loss of viscosity, as determined by this procedure, before a temperature of 80°C. is reached (Fig. 3). Undoubtedly, this is partly due to the low pasting temperature and narrower gelatinization range. The fact that fissures appear to exist in waxy starch granules and not in the regular starch granules might also increase their susceptibility to enzyme action. Apparently, the nonwaxy barley starches contain an enzyme-resistant fraction. This has been evident in all the barley starches we have examined to date, although differences occur in its magnitude. The ease of liquefaction of waxy barley starch might make waxy barleys better substrates for malting than normal barleys. This certainly suggests that the

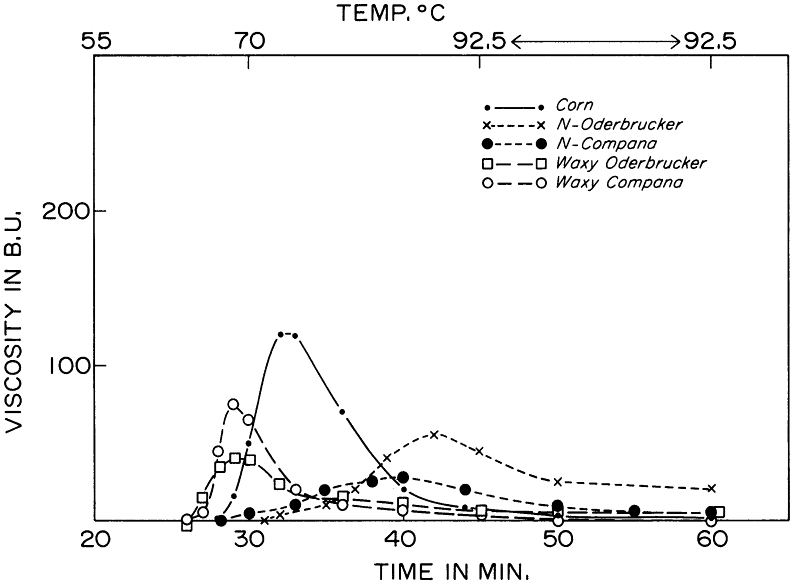

Fig. 3. Starch liquefaction: a comparison of the effect of bacterial α-amylase on various barley starches and the use of corn starch for comparative purpose; 7.6% starch and 0.006% HT-1000.

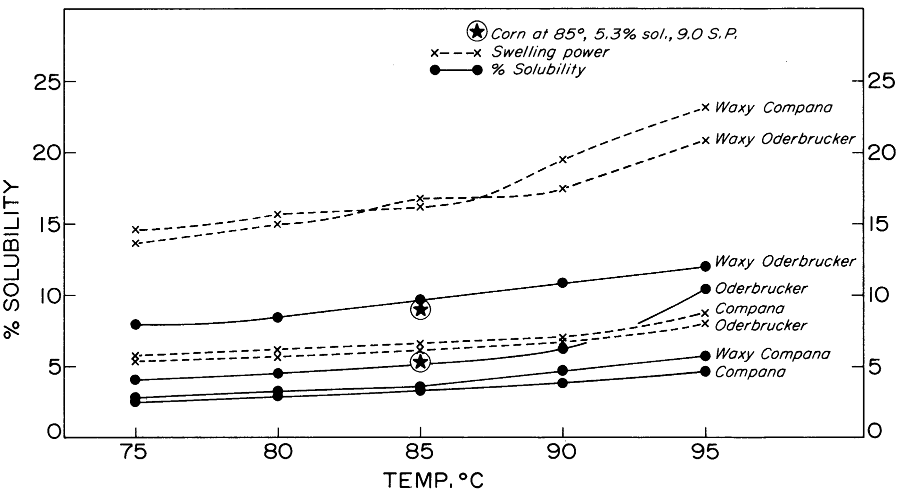

Fig. 4. Solubility and swelling power.

introduction of genes to increase the amylose content of brewing barleys as proposed by Merritt (14) is highly questionable. The ease by which this starch is attacked by enzymes would also suggest that it would make better feed and an ideal substrate for fermentation.

The solubility and swelling power are shown in Fig. 4.

A comparison of these values with those shown by Leach (11, p. 292) for other waxy cereals shows the barleys to have less than half the swelling power and (except in the case of rice) about half the solubility. However, a comparison of waxy sorghum with waxy Compana (they have identical Brabender curves) is revealing, since the Compana has less than half the swelling power and less than one third the solubility. This again indicates that Brabender curves involve something more than just granule swelling and granule solubility. These results suggest something unique about waxy Compana starch because its solubility is even less than that reported for high amylose corn (11, p. 292). This behavior cannot be caused by amylose, so it must involve some other factor—either some natural cross-binding or extremely long amylopectin chains, which may behave in a manner similar to amylose. An examination of the molecular structure of this cereal is in progress in our laboratory.

Acknowledgments

The authors wish to thank the laboratory personnel of the Montana Agricultural Experiment Station for analysis of ash, fat, and protein; Elmer Frahm for some of the iodine affinity and solubility and swelling power determinations; and especially Don Fritts of the Veterinary Research Laboratory for the photomicrographs.

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[Received November 28, 1972. Accepted December 16, 1972]