COMPARISON OF LEGUME AND WHEAT FLOUR CARBOHYDRATES. I. SUGAR ANALYSIS[1]

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ABSTRACT

Flour was obtained by dry milling of five legumes: navy bean, pinto bean, faba bean, lentil, and mung bean. Comparison of the chemical composition of the legume flours with that reported for hard red spring wheat flour showed that legume flours have less starch, starch damage and pentosan content but more protein, fat, ash, and acid-detergent fiber. The various legume flours have similar starch and moisture content. Faba bean, lentil, and mung bean flours contain approximately the same amount of damaged starch, which is more than that in the navy and pinto bean flours. Faba bean flour has the highest protein content and pinto bean has the lowest. Fat content is highest in navy bean flour; ash and acid-detergent fiber content is highest in mung bean flour. The total sugar content is higher in all legume flours than in wheat flour. The legume flours contain high levels of sucrose, stachyose and verbascose, but navy and pinto bean flours contain small amounts of verbascose. All legume flours also contain raffinose and glucose, but faba bean and lentil flour have certain different unidentified sugars. Wheat flour has no stachyose or verbascose but does have small amounts of maltose and fructose.

Legumes are the edible dicotyledonous seed of leguminous plants that belong to the Leguminosae family. These plants commonly grow in a wide range of conditions and climates. Their high nutritive values, particularly of protein, and their use as a protein supplement in foods or composite flour make them worthy of investigation. For composite flours, a main concern in addition to nutritional improvement is that the end product should retain the characteristics of the original legume. The gluten proteins of wheat are extremely important in producing a loaf of bread. The carbohydrates are the major component of most flours, however, and also are important in determining the quality of the end product. Knowledge of the carbohydrates in legume flours compared with those in wheat flour is essential to better understanding of the role of composite flours in bread baking.

Various workers have conducted analyses of edible legumes; investigations usually include protein, fat, moisture, fiber, ash, mineral, vitamin, and carbohydrate content. Carbohydrates are normally determined "by difference," ie, by deducting the sum of all other constituents from the total weight. This value for carbohydrate content includes all types of carbohydrates—from simple sugars to complex heteropolysaccharides—in addition to other substances such as organic acids and lignin (1). Most analyses have been conducted on whole legume seed or seed soaked in water, dehulled and ground (a bean paste). Recently, however, interest in the use of a composite legume and wheat flour has

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increased, and a few workers have analyzed the chemical composition of legume flours (2–5), but many legume flours have not been studied intensively.

The galactose-containing saccharides raffinose, stachyose, and verbascose occur in various legumes (6). The ethanol-soluble sugars extracted from horse bean (*Vicia faba*) include sucrose, raffinose, verbascose, stachyose, and higher molecular-weight-α-galactosides (7). The sugars in 70% ethanol extracts of chick pea and horse bean flours identified by paper chromatography are rhamnose, xylose, fructose, glucose, galactose, sucrose, maltose, raffinose, stachyose, and two unidentified sugars (2). Methyl-alcohol extracts of mung bean contain sucrose, raffinose, stachyose, verbascose, fructose, and glucose (8). According to a determination of oligosaccharides in some edible legume seeds (9), mung bean, broad bean and smooth pea also have small amounts of ajucose; reducing sugar ranges from 0.06 to 0.10% and nonreducing sugar from 5 to 7% in broad bean (*V. faba*), mung bean (*Phaseolus aureus*) and kidney bean (*P. vulgaris*).

This study compares the general chemical composition and sugars in various legume flours with those reported in wheat flour. Such data may clarify the possible function of legumes in composite flours for bread baking.

MATERIALS AND METHODS

Five legumes were studied: navy beans (*P. vulgaris*) grown in Michigan, pinto beans (*P. vulgaris*) and lentils (*Lens esculenta*) in North Dakota, the faba beans (*V. faba*) in Manitoba and the mung beans (*P. aureus*) in Oklahoma. The legume seeds were dehulled and dry milled in a Buhler laboratory experimental mill. We used the procedure described by Watson and associates (10), with minor modifications.

The glucoamylase method (11) was used to determine starch content in the legume flours. Starch damage, fat, ash, moisture, and protein content were determined by AACC Methods (12). The acid detergent fiber content of each legume flour was determined using Goering and Van Soest's method (13).

The extraction of total sugars from the legume flours was performed according to the method of Ponte and co-workers (14), except that the sample was extracted twice using the ternary solvent system. Individual free sugars were measured with a Technicon Sugar Auto-Analyzer System, using Abou-Guendia

TABLE I
Chemical Composition of Legume Flours[a]

Flour Source	Starch[b] (%)	Starch Damage[c] (%)	Protein[c,d] (%)	Moisture (%)	Fat[b] (%)	Ash[c] (%)	Acid-Detergent Fiber[b] (%)
Navy bean	51.6	2.71	21.2	10.6	4.93	3.45	3.44
Pinto bean	56.5	2.56	20.2	10.8	3.60	3.07	3.88
Faba bean	52.7	4.98	28.8	10.3	2.98	2.25	2.46
Lentil	52.3	4.69	24.0	10.5	2.82	2.54	1.97
Mung bean	52.0	4.72	23.7	9.1	2.58	4.30	8.58

[a]Values are an average of two determinations.
[b]Values are expressed on a moisture free basis.
[c]Values are expressed on 14% moisture basis.
[d]6.25 was used as a conversion factor from nitrogen to protein.

and D'Appolonia's method (15). The amount of each free sugar was calculated from the peak area, using the triangulation method and a standard curve prepared for each sugar.

RESULTS AND DISCUSSION

General Chemical Composition

Table I shows data on the general chemical composition for the legume flours. Starch content ranges from 51.6% for navy bean flour to 56.5% for pinto bean flour. All legume flours have a lower starch content than the 75–83% values reported for wheat flour (16).

Faba bean, lentil, and mung bean flours contain approximately the same amount of damaged starch, which is higher than amounts in navy and pinto bean flours (about 3%). In general, hard red spring wheat flour contains 5.5–7.8% damaged starch (16). The milling process damages starch (16), and a certain amount of starch damage is considered essential for best bread baking performance.

The protein content is higher for all of the legume flours (20.2–28.8%) than the 10–16% values reported for wheat flour (16). The moisture content of legume flours ranges between 9.1 and 10.8%, which is somewhat lower than the normal 12–14% in wheat flour (16). Navy and mung bean flours contain the highest and lowest amounts (4.93 and 2.58%) of fat, respectively. Hard red spring and hard red winter wheat flours reportedly contain 1.1–1.4% lipid (16), which is lower than the amount in legume flours. The ash content of legume flours ranges between 2.25 and 4.30%, which is considerably higher than the 0.36–0.39% reported for wheat flour (16). Mung bean flour has the highest acid-detergent fiber content (8.6%) and lentil flour the lowest (2.0%). All legume flours have higher acid-detergent fiber content, than the values reported for wheat flour (0.46%) (17).

Comparison of the chemical composition of the various legume flours in this study with other reports is difficult, because differences in the results may relate to factors such as the preparation of samples (the method used for milling) and the methods used in the determinations.

Sugar Analysis

Table II shows the total sugar content in the legume flours. Mung bean flour has the highest sugar content (7.22%) and faba bean flour the lowest (4.99%). All

TABLE II
Total Sugar Content of Legume Flours

Flour Source	Total Sugar[a] (%)
Navy bean	5.61
Pinto bean	6.71
Faba bean	4.99
Lentil	6.08
Mung bean	7.22

[a]Values are an average of three determinations and expressed on a moisture free basis in terms of sucrose.

of the legume flours have higher total sugar content than the 1.2–1.6% values reported for wheat flour (16). The higher sugar content in legume flours than in wheat flour is of particular interest if legume flours are to replace wheat flour partially in bread baking. Mung bean flour partially replacing wheat flour in bread baking greatly darkens the bread's crust color (18). The results of our study on total sugars would explain this in part.

TABLE III
Free Sugar Content of Legume Flours[a]

Flour Source	Sucrose (%)	Raffinose (%)	Stachyose (%)	Verbascose[b] (%)	Glucose (%)	Unknown I[c] (%)	Unknown II[b] (%)
Navy bean	2.23	0.41	2.59	0.13	0.04	...	...
Pinto bean	2.82	0.43	2.97	0.15	0.09	...	...
Faba bean	1.55	0.24	0.80	1.94	0.34	0.14	...
Lentil	1.81	0.39	1.85	1.20	0.07	...	0.90
Mung bean	1.28	0.32	1.65	2.77	0.05	...	...

[a]Values are an average of two determinations and expressed on a moisture free basis.
[b]Value calculated using stachyose for a standard curve.
[c]Value calculated using glucose for a standard curve.

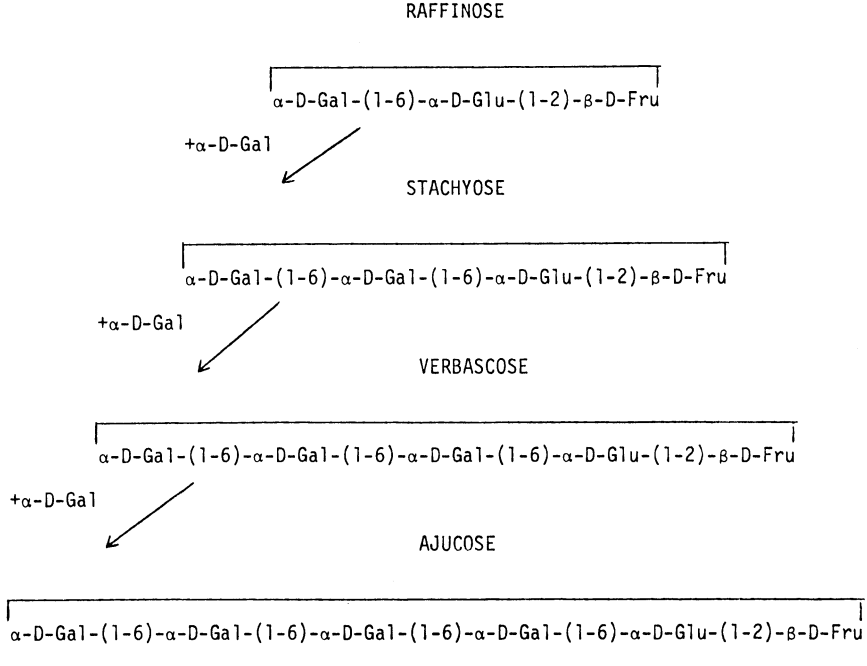

Fig. 1. Structural relationships of the raffinose oligosaccharides. Gal = galactose; Glu = glucose; Fru = fructose.

Table III shows the results of individual free sugar analyses. All five legume flours contain sucrose, raffinose, stachyose, verbascose, and glucose. Faba bean flour contains an unidentified sugar (unknown I) that differs from one of the unidentified sugars in lentil flour (unknown II).

Sucrose content is highest in the pinto bean flour (2.82%), followed by navy bean flour (2.23%). Lentil, faba bean, and mung bean flours contain smaller amounts of sucrose than do the navy and pinto bean flours, but sucrose is still a major sugar.

Legume flours in general contain similar amounts of the trisaccharide raffinose (Fig. 1). The stachyose content in all flour types, except faba bean flour, is as high and higher than the sucrose content. Faba bean flour has the lowest stachyose content (0.8%). Stachyose is a tetrasaccharide that has α-D-galactose linked to raffinose (Fig. 1). Navy and pinto bean flours contain only small amounts of verbascose, but the other legume flours all contain appreciable amounts. Mung bean flour contains higher amounts of verbascose than of other free sugars. Verbascose is a pentasaccharide in which α-D-galactose is linked to stachyose by an α-1,6 linkage (Fig. 1). The verbascose in mung bean flour was identified by collecting the sugar corresponding to the unknown peak as it eluted from the column, hydrolyzing it and measuring the ratio of component sugars. The ratio of component sugars, fructose:glucose:galactose (1:1:3), suggests that the sugar was verbascose. A similar ratio was reported previously (19). Because no standard for verbascose was available, the amount was determined using stachyose as a standard curve.

All legume flours contain only small amounts of glucose, ranging from 0.04 to 0.34%. Faba bean flour also contains an unknown (I) sugar in a small amount (0.14%). Lentil flour contains a relatively large amount (0.9%) of an unknown (II) sugar differing from that in the faba bean flour. The amounts of unknowns I and II were calculated using glucose and stachyose as standard curves, respectively.

The sum of the individual free sugars in each legume flour except mung bean flour agrees with the total sugar content (Table II). In this instance, the sum of the individual free sugars is lower than the total sugar content (Table II). Longer chain oligosaccharides apparently contribute to the total sugar content in mung bean flour.

Comparison of the free sugars in legume flours with those in wheat flour shows that wheat flour does not contain stachyose and verbascose; small amounts of maltose and fructose have been reported (16), however. Sucrose is the major free sugar in wheat flour but is about 10 times less than the content in the legume flours. The raffinose content in wheat flour is lower than in legume flours, and the glucose content is similar except in faba bean flour, which has higher glucose content.

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