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Oil content and fatty acid composition of some varieties of barley and sorghum grains

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RESUMEN

Contenido en aceite y composición en ácidos grasos de algunas variedades de granos de cebada y sorgo.

El contenido en aceite de granos de sorgo (media del 4.57%) fue aproximadamente el doble del de cebada (media del 2,27%). Los ácidos grasos más abundantes fueron el palmítico, oleico y linoleico, siendo bajo el ácido esteárico, esto tanto en cebada como en sorgo. El contenido del ácido linolénico fue mayor en la cebada que en el sorgo. En general la composición del aceite de sorgo fue similar a la del aceite de maíz y podría utilizarse para el cocinado y otros usos de los aceites comestibles.

PALABRAS-CLAVE: Aceite (contenido) - Acidos grasos (composición) - Cebada - Grano - Sorgo.

SUMMARY

Oil content and fatty acid composition of some varieties of barley and sorghum grains.

Oil content of sorghum grains (average 4.57%) was nearly twice that of barley (average 2.27%). Palmitic, oleic and linoleic acids were the most abundant fatty acids and that stearic acid content was low in barley and sorghum. The content of linolenic acid was higher in barley than in sorghum. The composition of sorghum oil, in general, was similar to corn oil and could be used for cooking and other uses of edible oils.

KEY-WORDS: Barley - Fatty acids (composition) - Grain - Oil (content) - Sorghum.

1. INTRODUCTION

In recent years a concerted effort has been mounted to enhance the nutritional quality of almost all agriculturally significant cereal grains. Barley occupies the fourth place in cereal crops. In Egypt, barley is used for animal feeding, but it is mainly used in the brewing industry. Sorghum is the fifth leading cereal crop in total world production after rice, wheat, corn and barley. In Egypt, it is a versatile plant which is grown for human consumption, feed, poultry nutrition and for industrial products (Gomaa 1996).

Lipids are considered the third storage material in barley grains. The level of lipid detected in barley grains has been reported to be low. Out of 8000 entries from the world barley collection, little variability in lipid content (2.1-2.6% with an average of 2.2%), as measured by nuclear magnetic resonance spectroscopy, was detected (Price 1972).

In Sweden, Johansson (1976) showed that the content of free lipids, bound lipids and total lipids varied in the rages 1.65-2.35, 1.42-2.09, and 3.15-4.25%, respectively, in barley. The lipid content was higher in foreign than in Swedish varieties. Only small differences were observed in fatty acid composition, and linoleic acid constituted 54-62% of total fatty acids in barley.

Fedak and De La Roche (1977) studied lipid and fatty acid composition in 21 strains of barley kernels and found that the oil content did not exceed 3.1%. In many strains it ranged from 2.5-3.1%, linoleic acid was present in highest proportion (50.7-57.9%) followed by smaller proportions of palmitic (18.3-27.0%), oleic (12.2%) and linolenic (4.3-7.1%) acids.

Bhatty et al (1974, 1975, 1979) have suggested that digestible energy of barley can be substantially improved, particularly for monogastric animals, by increasing its lipid content from the present average of about 2.0% (Bhatty et al 1974, Price 1972) to 3.0 or possibly 4.0%. The latter value increase the lipid content of barley close to that of corn, an ideal feed grain. Such an objective requires a genotype of barley having a high lipid content that is stable and genetically controlled.

Bhatty and Rossnagel (1980) determined the crude lipid contents of Riso 1508 and Bonanze barley by six different procedures. They found that the crude lipid contents varied from 4.0 to 7.4% for Riso and from 2.0-6.5% for Bonanze, according to the extraction procedure used. The differences in crude lipid contents were partly caused by the solvent system, the extraction condition and degree of purification of the crude lipid achieved with each of the six extraction procedures. The neutral lipids formed 74.9 and 65.2%, the glycolipids 7.3 and 25.6%, and the phospholipids 17.8 and 9.2% in Riso and Bonanza, respectively.

Madazimov et al. (1976) found that the lipid content of barley varied from 1.67 to 2.3%. The fatty acid composition of live regional varieties of Uzbek barley were studied. The main fatty acids found were linoleic (53.3-59.0%), palmitic (17.4-22.2%), oleic (16.3-19.7%), linolenic (3.0-6.5%) and stearic (1-2.2%). The fatty acid composition was shown to be unrelated to environmental factors.

Welch (1978) reported that Riso 1508 grown in the United Kingdom contained 53.7% linoleic, 23.5% palmitic, 16.8 oleic, 5% linolenic and 0.6% stearic acid.

Sang-Young et al. (1981) found that linoleic, oleic, palmitic and linolenic acids were the principal fatty acids in both free and bound lipids in barley. Anness (1984) found that barley contained 3.4-4.4% lipid (as fatty acid), the major fatty acids in free and bound lipid fractions were linoleic acid 52.1% and 54.8%, palmitic acid 24.8% and 30.3%, oleic acid 15.6% and 8.8%, respectively. Walter (1985) made a comparison of the content of total and some individual fatty acids in grains of nine barley varieties grown at 2 sites in Belgium. The varieties represented 6-rowed winter barley, and 2-rowed spring barley. The winter types contain more linolenic acid than spring types and 6-rowed barleys had less total fatty acids than 2-rowed barleys, due mainly to a low concentration of palmitic, oleic and linoleic acids. Analysis of variance showed that fatty acid content was affected by both the genotype and the environment and multiple regression analysis suggested that weather conditions affected lipid composition.

Man and Bruyneel (1987) studied the relationship between grain size and total fatty acid content and composition, as well as the contribution of grain size distribution to the variation of fatty acid contents between barley types in 9 varieties (6-rowed winter barleys, and 2-rowed spring barleys) fractioned according to grain size. They found that the total fatty acid content of the smaller grains was similar to that of the bigger ones. On average the proportions of saturated fatty acids (16:0 and 18:0) and of oleic (18: 1) were higher in larger grains than in small kernels, whereas the % of linoleic (18:2) and linolenic (18:3) acids proportions in were lower. The higher (18:1) and the lower (18:3) acids proportions in 2-rowed barleys compared to their 6-rowed counterparts, can be explained by indirect effect on the different grains size distribution between the barley types.

There have been several reports on the lipid composition of sorghum grains (Anderson et al. 1969, Wall Blessin 1969, Rooney 1973, 1978, Price and Parsons 1975, Badi et al. 1976, Weighrauch et al. 1976, Neucere and Sumrell 1980). With the exception of the study by Price and Parsons (1975), all previous studies were carried out with non-polar solvents that extract only the neutral and unbound lipids.

Differences may occur in the fatty acid profiles of agricultural products due to changes in soil and climate among other factors (Oyenuga 1968).

Sulins and Rooney (1975) and Weighrauch et al. (1976) found that the oil content of commercial varieties of sorghum ranged from 2.1 to 5.3% , while Neucere and Sumrell (1980) reported that the percent of oil of five varieties ranged from 2.66 to 3.49%.

Rooney (1978) reported that fatty acid composition of lipids from sorghum was palmitic, stearic, oleic, linoleic and linolenic in proportion of 10-14, 0.2-1, 28-42, 42-56 and 1-5%, respectively.

Neucere and Sumrell (1980) found that the distribution of major acids palmitic (11-13%), oleic (30-41%) and linoleic (33-49%) in the five varieties of sorghum was typical, but that minor components varied considerably (behenic 0-4%, lignoceric 0-15%, linolenic 1.8-4%, 5-eicosenoic 0.0-2.3%), and added that fatty acids were absent in some varieties and present in others.

Osagie (1987) found that the total lipid content of sorghum grains was 5.28% for SSH_3 variety and 3.68% for L187 variety and that the fatty acid composition of the total lipids was similar for all extraction procedures with linoleic acid being the predominant fatty acid.

Recently, Adeyeye and Ajewole (1992) found that palmitic, oleic and linoleic acids were the three most abundant fatty acids in sorghum oil and that stearic acid was in low quantities. On the other hand, linolenic acid was present in reasonable quantity, at (7.1%).

The improvement program of barley and sorghum crops currently carried out in the Agricultural Research Center in Egypt usually includes growing field comparisons of locally bred and imported varieties to select among them for yield and agronomic characters when grown under Egyptian environmental conditions. Oil content of the grains is not taken into consideration. Therefore, this study was carried out to compare locally bred and imported varieties under test with regard to oil content and fatty acid composition of their grains to find out the potentialities of taking oil content into consideration.

2. MATERIALS AND METHODS

2.1. Materials

Grains of five varieties of barley and six varieties of sorghum were obtained from «Field Crops Research Institute», Agricultural Research Center, Giza, Egypt. These varieties are:

1. Barley: three locally bred varieties: (i) Giza 123 and Giza 124, six-rowed barley (*Hordeum Vulgare*), and Giza 128, two-rowed barley (*H. distichum*), and

(ii) two imported varieties: C.C 89, six-rowed hulless barley (*H. Vulgare*).

Two-rowed varieties are known to be the best for brewing. The ear carries two rows of grains. The husks which are thinner give less extract containing undesirable material which would impair the quality of beverage industry product. In six-rowed varieties, the ear carries six rows of grains, the individual grains are not so well developed as in two-rowed varieties and the husk is thicker.

2. Sorghum: six varieties of sorghum (*Sorghum bicolor* L. Moench), two locally bred: Giza 15 (creamy grains, low tannin variety), and Giza 129 (yellow grains, low tannin variety), and four imported varieties: Dorado (white grains, low tannin variety), N.E.S. 1007 (white with red spots grains, low tannin variety), Framida (brown grains, high tannin variety), and IS 2248 (red grains, high tannin variety). N.E.S. 1007 was imported from Lebanon and the other four varieties were obtained from the International Crops Research Institute for Semi Arid Tropics.

2.2. Methods

The tests were carried out on seed composite samples representing three field replicates from each variety.

Determination of Oil Content

The oil content of the grains was determined according to the procedures reported in the A.O.A.C. (1970) and expressed as percent of whole grain. Two tests were carried out from each sample.

Determination and Identification of Fatty Acids

Fatty acid composition was determined by gas liquid chromatography of the methyl esters using a Varian Model 3700 gas chromatograph with a flame ionization detector. A capillary glass column (AW 80/100, 2 cm, SST, 1/4 ID) packed with 15% DEGS was used. Two injections were made from each sample. The operating conditions were: Injection temperature, 240°C; detector temperature, 280°C; column temperature, 70°C; 4°C/min to 190°C; the nitrogen, hydrogen and air flow rates were 30, 30 and 300 ml/min, respectively.

Methyl esters of fatty acids were prepared from an aliquot of total lipid with 5% HCl in anhydrous methanol (w/w) according to the method of Fedak and De La Roche (1977).

Identification of the fatty acids on the chromatogram was made by comparing the retention time of the lipid methyl esters with those of known mixtures of methyl esters run on the same column under the same conditions. The fatty acid composition was expressed as area percentage of all methyl esters present.

Statistical Analysis

For comparing the statistical significance of the differences between varieties, the precision of the results of each test (E%) was determined from tests carried on the samples of Giza 123 (barley) and Dorado (sorghum) varieties, according to the following formula (ASTM, 1967):

$$E\% = [(t \times SE) / X'] \times 100, \text{ where:}$$

E% = Precision of the test result average expressed in per cent of the average.
t = Probability value at 5% and at 1% levels of significance.
SE = standard error of test results.
X' = Test average value.

Confidence limits for each test result could be calculated as E% x test value. A difference between two test values (averages) that is greater than the sum of the two confidence limits at 5% probability level is regarded as statistically significant at this level. The same applies for 1% probability level.

3. RESULTS AND DISCUSSION

3.1. Oil Content and Fatty Acid Composition of Barley Grains

The lipid content of the five varieties of barley varied from 1.90 to 2.87% (Table I). Generally, the amount of lipid detected was low, being 1.90 and 1.92 in two varieties (Giza and C.C89) and slightly higher in the other three varieties, being 2.56, 2.87 and 2.08% for Giza 124, N.B.Y.T. and Giza 128, respectively. The results are similar to those reported by Price (1972), Bhatty et al. (1974), Fedak and De La Roche (1977), Rabih (1981), Lasztity (1985) and Linko et al. (1989).

The results in Table I also show that barley oil generally contained about 22.63% saturated fatty acids with palmitic being the principal saturated fatty acid, followed by stearic acid. The unsaturated fatty acids level was about 77.29% of the total fatty acids, with linoleic acid comprising 39.49-53.40%, of the total amount followed by oleic and linolenic acids (Table I). These results are in agreement with those reported by Bhatty and Rossnagel (1980).

The data revealed that the ratio of saturated to unsaturated fatty acids was not appreciably different

Table I
Fatty acid composition of oils extracted from five varieties of barley grains

Oil Content and Fatty Acid	Variety/Composition[a]					Precision (E%)	
	Giza 123	C. C89	Giza 124	N.B.Y.T.	Giza 128	5%	1%
Oil Content[b]	1.9	1.92	2.56	2.87	2.08	2.50	3.29
Heptanoic (C7:0)	0.17	—	—	—	—	3.25	4.28
Lauric (C12:0)	0.35	0.55	0.40	0.06	—	6.31	8.31
Myristic (C14:0)	1.49	0.39	0.03	0.38	—	3.52	4.63
Palmitic (C16:0)	18.17	17.95	19.18	17.72	23.79	3.34	4.40
Palmitoleic (C16:1)	2.87	1.22	0.31	1.22	—	3.56	4.68
Stearic (C18:0)	4.58	2.51	0.28	2.01	2.99	3.01	3.97
Oleic (C18:1)	21.18	22.40	21.48	13.96	14.55	3.39	4.46
Linoleic (C18:2)	44.97	49.30	53.40	39.49	47.50	3.25	4.28
Linolenic (C18:3)	6.06	5.68	4.65	25.07	11.16	3.64	4.80
Total saturates	24.92	21.40	19.89	20.17	26.78	3.32	4.37
Total unsaturates	75.08	78.60	79.84	79.74	73.21	3.20	4.21
Total saturates/Total unsaturates	0.33	0.27	0.25	0.25	0.37		

[a] percent of total fatty acids.
[b] percent of whole grain.

between Giza 124 (hulled barley) and N.B.Y.T. (hulles barley), but was high (0.37) in Giza 128 (two-rowed) followed by Giza 123 (0.33) and C.C89 (0.27). The fatty acid composition showed considerable variation among the five varieties examined. For example, oleic acid ranged from 13.96 to 22.40%, linoleic acid ranged between 39.49 and 53.4% and linolenic acid ranged between 4.65 and 25.07% of the total fatty acids. In other words, the variety C.C89 contained oleic acid 1.6 times more than that present in the oil of variety N.B.Y.T. Meanwhile, N.B.Y.T. variety contained more linolenic acid 4.41 times as compared to that present in the oil of the variety C.C89. The variety Giza 124 also contained linoleic acid 1.35 times more than that present in the oil of the N.B.Y.T. variety, while N.B.Y.T. variety contained linolenic acid 5.39 times compared to that present in the variety Giza 124. It is clear that the magnitude of variation is greater in the case of linolenic acid than in oleic and linoleic fatty acids (Table I). Thus the major fatty acids of all barley varieties were composed of linoleic, palmitic and oleic. These results are similar to those of Fedak and De La Roche (1977) and Bhatty and Rossnagel (1980). All varieties tested contained lauric (0.06-0.55%), myristic (0.03-1.49%), palmitoleic (0.31-2.87%) and stearic (0.28-4.58%) acids. Because linolenic acid is one of the essential fatty acids, its concentration in barley is of nutritional significance, however in the case of very high concentration of linolenic acid, such as that has been found in N.B.Y.T. variety, may lead to rancidity problems during storage (De La Roche et al. 1976). Hence, selection of varieties with a lower degree of polyunsaturation (linolenic acid) to minimize lipid oxidation and with higher lipid levels may be necessary.

3.2. Oil Content and Fatty Acid Composition of Sorghum Grains

The oil content in grains of six varieties of sorghum ranged from 3.95 to 5.63% (Table II). From the data presented it could be seen that the highest oil content was found in IS2284 (high tannin variety), while the lowest percentage was found in Giza 15 variety. Sorghum grains also contained a higher percentage of oil than barley grains. The oil content of sorghum obtained in this work agreed with that reported by Adeyeye and Ajewole (1992) 3.9%, but was higher than that reported by Neucere and Sumrell (1980). The lipid content was higher in two varieties (Framida and IS2284) as compared to the other four (Dorado, N.E.S. 1007, Giza 15 and local 129).

The fatty acid composition of the six varieties of sorghum are shown in Table II. Palmitic, oleic and linoleic acids were the most abundant fatty acids in

all six varieties tested. This is the case of most plant seed oil (Girgis and Turner 1972, Raie and Latif Iqbal 1983 , Grompone 1988, Ajewole and Adeyeye 1991). Stearic acid was found in low quantities in all varieties. It ranged from 1.51 to 3.33% whereas palmitic acid ranged from 14.21 to 17.92%. Lauric and myristic acids were also found in low percentages. The content of lauric acid ranged from 0.22 to 0.17%, but myristic acid from 0.1 to 2.27%. Linolenic acid was present in quantities (1.04-2.07%).

Table II
Fatty acid composition of oils extracted from six varieties of sorghum grains

Oil Content and Fatty Acid	Variety/Composition[a]						Precision (E%)	
	Dorado	N.E.S1007	Local 129	Giza 15	Framida	IS2284	5%	1%
Oil Content[b]	4.41	4.16	4.14	3.95	5.14	5.63	3.24	4.26
Lauric (C12:0)	1.06	0.53	0.44	1.17	1.04	0.22	3.91	5.14
Myristic (C14:0)	0.14	0.30	0.38	0.10	2.27	0.59	3.55	4.67
Palmitic (C16:0)	15.37	16.60	15.72	17.33	14.21	17.92	3.23	4.26
Palmitoleic (C16:1)	2.04	2.83	3.60	2.00	2.41	1.56	3.52	4.63
Stearic (C18:0)	2.89	3.21	3.33	1.70	2.57	1.51	3.34	4.40
Oleic (C18:1)	37.98	33.67	29.15	32.98	32.16	37.34	3.34	4.40
Linoleic (C18:2)	38.29	41.77	45.74	43.43	44.29	39.19	3.24	4.27
Linolenic (C18:3)	2.07	1.08	1.64	1.30	1.04	1.65	4.00	4.27
Total saturates	19.46	20.64	19.87	20.30	20.09	20.24	3.26	4.29
Total unsaturates	80.38	79.35	80.13	79.71	79.90	79.74	3.28	4.25
Total saturates/Total unsaturates	0.24	0.26	0.25	0.25	0.25	0.25		

[a] percent of total fatty acids.
[b] percent of whole grain.

The results in Table II also indicate that the content of palmitoleic acid ranged from 1.56 to 3.60%. All varieties showed very high levels of unsaturation ranging from 79.35 to 80.38%. The content of linoleic acid was between 38.29 and 45.74% whereas oleic acid ranged from 29.15 to 37.98%. The essential fatty acid content (C 18:2 +C 18:3) was also high in all varieties examined ranging from 40.35 to 47.38%. The values for major components are in general agreement with those reported by Wall and Blessin (1970) and Neucere and Sumrell (1980).

Generally, sorghum oil is similar to corn oil in its composition to a great extent and could be used for the same purposes. Moreover, the highest content of essential fatty acids in sorghum make it more nutritious than other cereals.

It could be seen from these results that palmitic, oleic and linoleic acids were most abundant fatty acids in both barley and sorghum grains. The total saturated fatty acids was slightly higher in barley, being on average, 22.63% for barley and 20.1% for sorghum. On the other hand, the results obtained revealed that the level of linolenic acid is comparatively high in barley grains, since it represented, on average 10.52% of the total fatty acids, whereas sorghum grains contain, on average 1.46% linolenic acid.

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