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Studies of Saudi Arabian Locally Produced Wheat Germ

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ABSTRACT

Local wheat germ (LWG) had higher protein and oil but lower crude fibre, total sugar, and carbohydrates than commercial wheat germ (CWG). Variation in amino acid compositions occurred in both samples. Laboratory extracted commercial wheat germ oil (LECWGO) had the highest acid and peroxide values while commercial wheat germ oil (CWGO) was the lowest in unsaponifiable matter. Palmitic, stearic, oleic, linoleic and linolenic acids were found. Local wheat germ oil (LWGO) was the richest in alpha and beta tocopherols. Gamma tocopherol was only found in CWGO.

INTRODUCTION

Wheat germ comprises a small portion of wheat kernel and is usually separated during milling to improve keeping quality of the flour. Wheat germ products are of nutritional importance because of their high contents of tocopherols (Eckey, 1954; Kent, 1983). Uses of the products include cocoa substitutes for cakes, biscuits, and other dietary products (Kent, 1983).

Wheat germ varies in its chemical and amino acid compositions, depending on variety and grade (Hepburn *et al.*, 1960; Stevens *et al.*, 1963; Aykroyd & Doughty, 1970; Inglett, 1973). The crude wheat germ oil is characterized by higher free fatty acids, tocopherols, and unsaponifiable matter and contains more than seven fatty acids (Formo *et al.*, 1979).

In Saudi Arabia, wheat production has dramatically jumped during the last five years, from 199 000 tons in 1981 to more than 2·54 million tons in

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1986 (DESS, 1987). Wheat milling in the country is mainly carried out by Grain Soils and Flour Mills Organization at a daily capacity of nearly 3750 tons (GSFMO, 1986). However, the separated germs have not properly been utilized even though foreign commercial wheat germ products are locally marketed. This might be partially due to lack of research highlighting the quality of local germ products. Therefore, this research was to investigate and compare the quality of locally produced wheat germ and its crude oil against the imported commercial products, hoping this would promote their uses as food supplements by the fast growing food industry in the Kingdom of Saudi Arabia.

MATERIALS AND METHODS

Sample collection

Locally produced wheat germ samples were obtained from Grain Soils and Flour Mills Organization, Riyadh, Saudi Arabia. Commercial wheat germ (Gerble Revel, France) and commercial wheat germ oil (Provence, France) samples were bought from a local supermarket.

Chemical composition

Moisture, oil, protein, ash, crude fibre, reducing sugars, and total sugars were determined according to AOAC (1980). Total carbohydrate was calculated by difference. Minerals were measured by wet-ashing (AOAC, 1980) and determined using an IL 251 atomic absorption spectrophotometer. Total phosphorus was separately determined by the modified method described by Abu-Lehia (1987). Protein was hydrolyzed with 6N HCl (LKB, 1983) and the amino acids were determined on a LKB Amino Acid Analyzer Model 4150 ALPHA.

Oil extraction and physico-chemical analysis

Oils were extracted from local and commercial wheat germ samples by petroleum ether (40–60°C) using a Soxhlet apparatus. The laboratory-extracted oils, along with the commercial wheat germ oil, were analyzed for specific gravity, refractive index, acid value, peroxide value, iodine number, saponification number, and unsaponifiable matter according to IUPAC (1979).

Gas chromatography (GC)

The fatty acid compositions of oils were determined by gas chromatography according to the procedure described by Metcalfe *et al.* (1966). Fatty acid methyl esters were identified on a 3700 gas chromatograph (Varian) with a flame ionization detector at 250°C. The hydrogen, air, and nitrogen flow rates were 30, 300, and 40 ml/min, respectively. A 1 μl sample was injected on a 200 cm × 6·25 mm column which was packed with 15% OV-275 on 80/100 chromosorb WAW. The temperature of the injection and column was 150°C. Comparison between the peaks of the samples and those of the standards, run on the same column under the same conditions, was made for identification.

High-performance liquid chromatography (HPLC)

The procedures of Carpenter (1979) and Speek *et al.* (1985) were adapted for separation and quantitation of tocopherols in wheat germ oils. The HPLC separation was performed on a 0·78 × 30 cm μ-Porasil column (Waters Modular System). The mobile phase (1·5% iso-propyl alcohol in hexane) was introduced by a solvent delivery pump model M-45 at a flow rate of 1·5 ml/min. The system was attached to injector model U6k through which a 50 μl sample was injected. The absorption maxima for tocopherols was obtained at 295 nm on a LC-481 spectrophotometer. The peak areas for the calibration curves and for the calculation of tocopherol amounts in the wheat germ oil samples were measured by a data module Model 730 integrator. The chart speed was 1 cm/min, and the sensitivity was 0·2.

Standardization was made by reagent grade alpha, beta, and gamma tocopherols to determine the retention times of these components. Delta tocopherol was not located. Alpha tocopherol was obtained from Fluka Chemicals (Hauppauge, NY), and beta and gamma tocopherols were obtained from Supelco, Inc. (Bellefonte, PA). Each standard is made up in 1·5% isopropyl alcohol (IPA) in hexane at a concentration of 0·05% w/v from which 10, 20, 30, 40 and 50 μl were injected to construct a calibration curve for each standard. Five grams of oil were dissolved in 100 ml 1·5% IPA in hexane and 50 μl was injected onto the HPLC column. Individual tocopherols were then calculated from the standards' calibration curves.

RESULTS AND DISCUSSION

Chemical composition

Proximate composition of local and commercial wheat germs is presented in

TABLE 1
Proximate Composition[a] of Local and Commercial Wheat Germs (% weight)

Item	*LWG*[b]	*CWG*[c]
Moisture	6·95	5·32
Oil	10·70	9·09
Protein (N × 5·7)	33·8	30·0
Ash	5·09	5·18
Crude fibre	2·61	3·50
Reducing sugars	3·49	3·43
Total sugars	16·66	17·90
Carbohydrates	40·85	46·9

[a] On dry basis, means of triplicate analyses.
[b] LWG = local wheat germ.
[c] CWG = commercial wheat germ.

Table 1. Local wheat germ (LWG) was higher in oil and protein contents but lower in fibre, total sugar and carbohydrates than those found in commercial wheat germ (CWG). Aykroyd & Doughty (1970) reported lower means of data for oil, protein and ash. Higher crude fibre and higher ash is usually due to contamination of the germ with the bran during the milling process. Crude fibre and sugar contents in this study fell within the range of 1·7 to 5·5 (Neumann-Pelshenke, 1954; Fraser & Holmes, 1959) and 12·5 to

TABLE 2
Mineral Composition of Local and Commercial Wheat Germs (mg/100 g)[a]

Mineral	*LWG*[b]	*CWG*[c]
Na	—[d]	14·9
K	805	620
Ca	5·6	11·5
Mg	154	176
Fe	4·5	8·0
Cu	—	—
Zn	12·2	13·7
P	806	1010
Mn	18·9	18·6

[a] On wet basis, means of duplicate analysis.
[b] LWG = local wheat germ.
[c] CWG = commercial wheat germ.
[d] trace

21·4 (Neumann-Pelshenke, 1954), respectively. Linko *et al.* (1960) reported as high as 28·6% sugar content in wheat germ.

Table 2 shows the concentrations of nine minerals found in wheat germ samples. LWG was mainly higher in potassium and slightly higher in manganese but lower in the other minerals than those of CWG. Garcia *et al.* (1972) reported the mineral contents of wheat germ in mg/100 g using atomic absorption spectroscopy to be: phosphorus, 1080; potassium, 950; magnesium, 300; calcium, 40; sodium, 10; iron, 9·8; zinc, 14·3; manganese, 14·8; and copper 1. Variation in concentrations might be due to varietal differences and/or to the contamination of the germ with varying amounts of bran.

Amino acid profiles of local and commercial wheat germs are given in Table 3. The amino acid profile showed the concentrations of seventeen amino acids determined by acid hydrolysis. The values were generally lower in both LWG and CWG, when compared to those reported by Hepburn *et al.* (1960) and Stevens *et al.* (1963) for wheat germ. However, wheat germ

TABLE 3
Amino Acid Composition of the Protein in Local and Commercial Wheat Germs[a] (g/16 g nitrogen recovered)

Amino acid	*LWG*[b]	*CWG*[c]
Aspartic	5·31	5·13
Threonine	2·23	2·06
Serine	2·35	2·13
Glutamic acid	9·43	8·96
Proline	2·76	2·51
Glycine	3·08	3·32
Alanine	4·03	3·57
Cystine	0·26	0·04
Valine	3·22	3·08
Methionine	1·41	1·70
Isoleucine	2·07	2·21
Leucine	4·07	4·20
Tyrosine	1·74	0·95
Phenylalanine	2·52	2·14
Histidine	1·90	1·75
Lysine	4·09	4·44
Ammonia	1·10	0·89
Arginine	4·80	4·65

[a] On wet basis, means of triplicate analysis, tryptophan not determined.
[b] LWG = local wheat germ.
[c] CWG = commercial wheat germ.

samples in this study had higher nitrogen percentages than those reported by Hepburn *et al.* (1960). The procedure had been repeated several times to obtain better recovery but no significant improvement was achieved. CWG was slightly higher in glycine, isoleucine, leucine, lysine and methionine. Differences might be due to the genotype of the variety and environmental conditions.

Physico-chemical characteristics and fatty acid composition

Table 4 shows physico-chemical characteristics and fatty acid composition of wheat germ oils. Values of physico-chemical constants for local wheat germ oil (LWGO), laboratory extracted commercial wheat germ oil (LECWGO), and commercial wheat germ oil (CWGO) were compared with AOCS standards for wheat germ oil (Formo *et al.*, 1979). These AOCS standards are as follows: specific gravity 25/25°C, 0·925–0·933; refractive index 40°C, 1·469–1·478; iodine number, 115–129; saponification number 179–190; and unsaponifiables, 2–6%. The oil samples had lower specific gravity but higher refractive index. LWGO and CWGO were slightly higher

TABLE 4
Physico-chemical Characteristics and Fatty Acid Compositions of Wheat Germ Oils

Assay	*LWGO*[a]	*LECWGO*[b]	*CWGO*[c]
Specific gravity 25 (24°C)	0·916 5	0·918 1	0·920 8
Refractive index (25°C)	1·475 0	1·475 5	1·475 6
Acid value	9·63	21·35	4·52
Peroxide value	10·24	19·13	12·75
Iodine number	126	129	129
Saponification number	193	187	192
Unsaponifiable matter (%)	3·71	4·84	1·70
Fatty acid composition (Area %)			
C_{16}	18·91	21·18	10·97
C_{18}	1·84	Trace	4·23
$C_{18:1}$	17·85	13·54	20·06
$C_{18:2}$	55·42	57·86	62·07
$C_{18:3}$	5·99	7·42	2·66
Saturated fatty acids	20·75	21·18	15·2
Unsaturated fatty acids	79·26	78·82	84·79
P/S Ratios[d]	2·96	3·08	4·26

[a] LWGO = local wheat germ oil.
[b] LECWGO = laboratory extracted commercial wheat germ oil.
[c] CWGO = commercial wheat germ oil.
[d] P/S = sum of all polyunsaturated acids/sum of all saturated acids.

in saponification number which is a measure of the average molecular weight of the glycerides. Specific gravity is known to bear an inverse relationship with molecular weight but a direct one with the degree of unsaturation (Pryde, 1980). Both acid value and peroxide value were extremely high in LECWGO. Acid value is a measure of the degree of lipid hydrolysis and separation of fatty acids from glycerol while peroxide value is a measure of lipid oxidation. Commercial wheat germ, from which the oil was extracted, had been on the shelf for a long time according to the production date and oil deterioration is quite possible. In addition, wheat germ oil is generally characterized by higher free fatty acids (Formo *et al.*, 1979). The iodine numbers in LECWGO and CWGO were above the average of AOCS and this indicates a higher degree of unsaturation and consequently higher refractive indices (Pryde, 1980).

CWGO contained less unsaponifiable matter, 1·7%, compared to 3·71 and 4·84% for LWGO and LECWGO, respectively. CWGO might have been commercially treated or processed since it was very clear unlike LWGO and LECWGO which had a cloudy appearance. Higher unsaponifiables are a characteristic of wheat germ oil. Itoh *et al.* (1973) found these unsaponifiables to include polar compounds (7%), triterpene alcohols (7%), methylsterols (5%), and sterols (81%).

The fatty acid profiles of LWGO, LECWGO, and CWGO were identical (Table 4). However, stearic acid was found in only trace amounts in LECWGO. CWGO was the most unsaturated oil with a particularly high level of linoleic acid in conjunction with a lower level of linolenic acid. The higher level of linolenic acid in LECWGO adversely affected the stability of the oil which led to a higher peroxide value. Nelson *et al.* (1963) and Formo *et al.* (1979) reported palmitic, palmito-oleic, stearic, oleic, linoleic, linolenic and C_{20}–C_{22} saturated fatty acids present in crude wheat germ oil. The P/S ratios in Table 4 were obtained by dividing the total polyunsaturates by the total saturates, regardless of chain length. CWGO had the highest P/S ratio (4·26) while the lowest P/S ratio was that of LWGO (2·96). P/S ratio is of importance with regard to lipid intake and health relationship.

Tocopherols

The HPLC elution profiles of wheat germ oils are shown in Fig. 1. Alpha and beta tocopherols were found in all samples while gamma tocopherol was in detectable amounts only in CWGO. The profile for all samples, as indicated by the chromatographic peaks, is characteristic of a high alpha tocopherol oil.

The composition of tocopherols in oil samples is presented in Table 5. Alpha tocopherol, which has the highest vitamin E activity, was found in

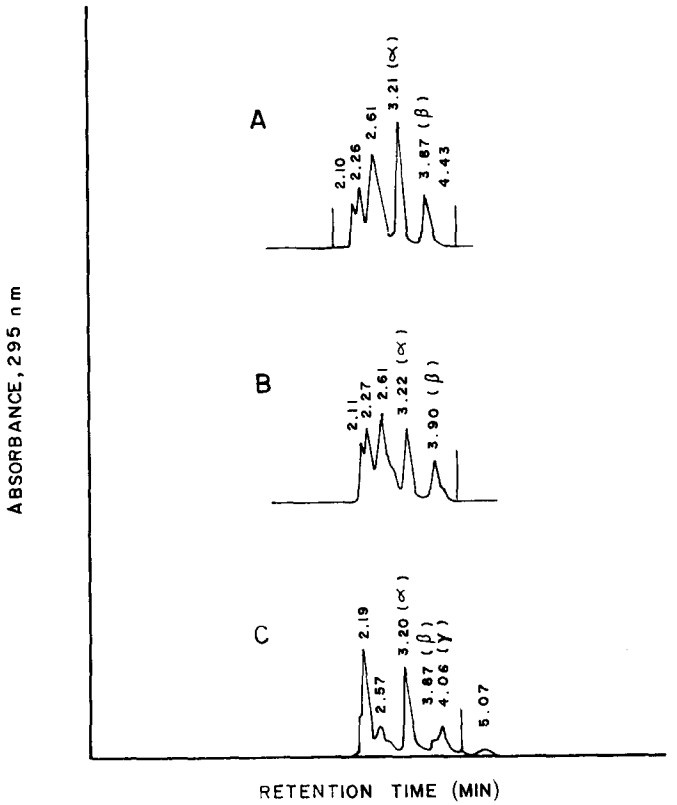

Fig. 1. HPLC chromatograms of tocopherols in local wheat germ oil (A), laboratory-extracted commercial wheat germ oil (B), and commercial wheat germ oil (C). Conditions are given in the text.

higher amounts in all samples with LWGO being the richest (236 mg/100 g) in this form. CWGO contained the lowest amounts of beta tocopherol but was the only sample to contain appreciable amounts of gamma tocopherol (66·4 mg/100 g). Muller-Mulot (1976) reported 1179, 398, 493, and 118 mg/kg of alpha, beta, gamma, and delta tocopherols, respectively, in wheat germ oil. Variations in tocopherols might be due to natural variation in wheat germ oils which are generally considered extraordinary sources of these components. Tocopherols are found in the unsaponifiable fraction and are frequently determined mainly in fats and oils because of their dual importance as vitamin E and natural antioxidants.

Table 5 shows the ratios of alpha tocopherol to polyunsaturated fatty acids (PUFA). This ratio was suggested as a measure of the adequacy of dietary vitamin E (Harris *et al.*, 1963). The authors recommended a ratio of 0·6 mg of alpha tocopherol to 1 g of PUFA. The data in Table 5 indicate much higher ratios than 0·6 mg/g particularly for LWGO. This was expected

TABLE 5
Composition of Tocopherol and Alpha Tocopherol to Polyunsaturated Fatty Acid (PUFA) Ratios in Wheat Germ Oils

Sample	*Tocopherols (mg/100 g)*[a]			*Alpha-T(mg)/ PUFA*[b] *(g)*
	Alpha	*Beta*	*Gamma*	
LWGO[c]	236	119	ND[f]	3·84
LECWGO[d]	171	92·4	ND	2·62
CWGO[e]	173	31·6	66·4	2·67

[a] Average of three determinations.
[b] PUFA = $\%C_{18:2} + \%C_{18:3}$.
[c] LWGO = local wheat germ oil.
[d] LECWGO = laboratory-extracted commercial wheat germ oil.
[e] CWGO = commercial wheat germ oil.
[f] ND = not detected.

since wheat germ oils are major dietary sources of both tocopherols and PUFA. Dorothy *et al.* (1976) calculated the ratios of alpha tocopherol to PUFA in some selected vegetable oils and found the highest ratio of 2·26 mg/g for olive oil and the lowest ratio of 0·03 for apricot kernel oil.

This study indicates that the quality of LWG and LWGO are comparable or even better, particularly in protein and oil contents as well as in alpha and beta tocopherols concentrations, than those of similar imported products.

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