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Lipids in Wheat Flour Streams

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ABSTRACT

Lipids play an important role in determining the quality of wheat flour and its suitability for different bakery products. The lipid content and fatty acid composition in various flour streams showed a wide variation. The free lipid content varied from 0·1 to 1·9% (db) and bound lipid content from 0·2 to 2·1% (db) in different flour streams. The amount of bound lipid was more in reduction streams. The palmitic and linoleic acids were the predominant fatty acids present in free and bound lipids. These fatty acids were found to be higher in the 'III' 'Break coarse', 'IV' 'Break filter', 'III' 'Break fine', '1st' and '4th' 'middling'. The studies showed that the reduction passage flours had more of bound lipids indicating the presence of polar lipids.

Keywords: lipids, fatty acids, wheat, milled streams.

INTRODUCTION

Roller flour milling aims at gradual reduction in size of wheat by passing it through a series of break and reduction rolls to enable maximum removal of bran and germ and obtain fine white flour for use in bakery products. In this process, wheat is opened up and the endosperm released and separated from the bran coats in break rolls and the resulting endosperm grits are reduced to fine flour in subsequent reduction rolls. The portion of endosperm from which the flour is obtained in each break or reduction rolls is different. The straight run flour obtained in a roller flour mill contains materials of all the streams.

It is known that the composition of endosperm of wheat varies depending on its location in the grain[1]. The composition of the central portion of the endosperm is quite different from that near the periphery[2]. Hence, the composition of each break or reduction stream will be different due to different portion of endosperm and coming into it, in addition to other grain components like pericarp, aleurone layer and seed coat.

Though considerable work was done on wheat protein, the information regarding lipid content and their functional characters are limited. This is because of lesser variation in the lipid content among different wheat varieties as compared to protein. Lipids have been reported to influence greatly the baking quality of flours and particularly of bread[3]. Among the lipids, polar lipids have been reported to have a more beneficial effect on loaf volume[4,5]. Chung *et al.*[6] reported a good correlation between polar lipids and loaf volume of bread ($r=0{\cdot}877$; $p<0{\cdot}01$). Most of polar lipids are found in bound form complexing with protein and starch[2]. Fatty acids and particularly, unsaturated fatty acids are reported to strengthen the gluten by way of oxidation of 'SH' group[3,7]. However, there is no scientific data available on the content and type of lipids in different flour streams. This information is necessary in order to develop flour of specific quality is for use in different bakery and traditional products. This could be achieved for example by blending selected flour streams. Therefore, studies were carried out to determine the lipid content

ABBREVIATIONS USED: GC: gas chromatography; A.A.C.C.: American Association of Cereal Chemists; DEGS: diethylene glycol succinate.

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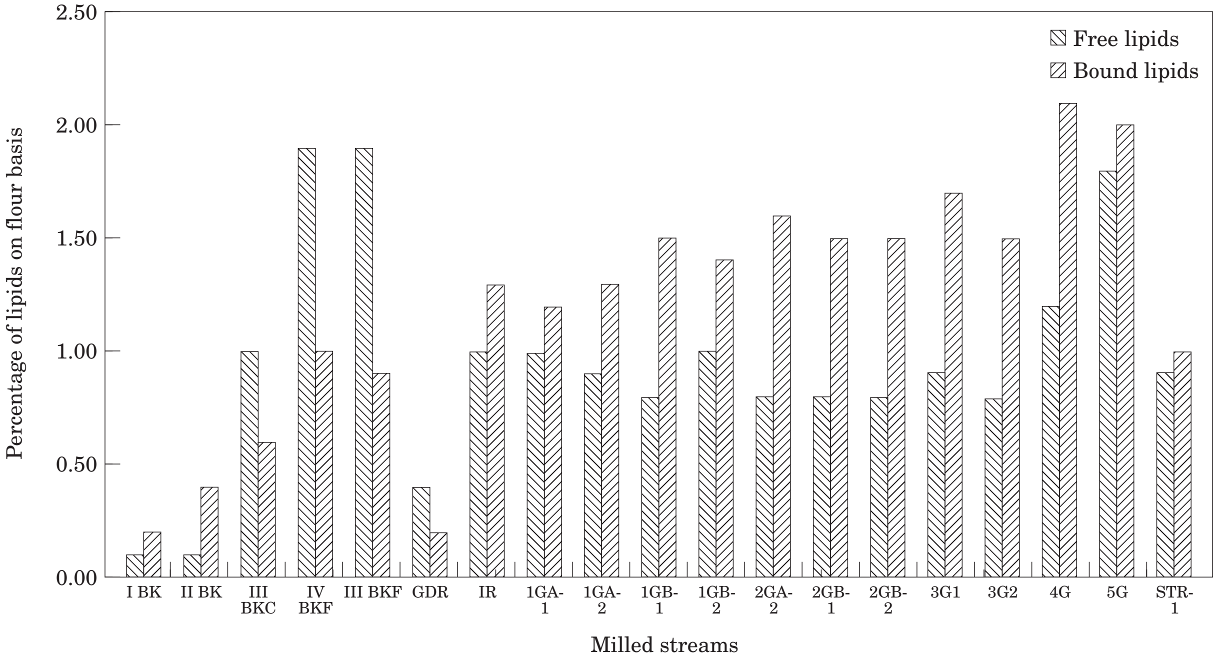

Figure 1 Comparison between free and bound lipid content of different flour streams.

and its fatty acid composition in various flour streams.

MATERIALS AND METHODS

Raw materials

Break and reduction flour streams were obtained from a commercial roller flour mill which separates 50–52% refined wheat flours, 10–12% semolina and 8–10% resultant atta and 20–22% bran. Commercially available, medium hard, aestivum wheat having grain hardness of 11 kg/grain and hectolitre weight of 82 kg/hectolitre was used for obtaining different streams. The mill (Muhlenbau, Germany) with the capacity of 80 tonnes/day had four break rolls and five reduction rolls. In break systems, five different flour streams one each from I and II Break, III Break both coarse and fine passages and IV Break filter passage were collected. In a reduction system, in total twelve flour streams, one each from semolina passage (IR) and grader passage (GDR), four from 1st middling (1GA1, 1GA2, 1GB1, 1GB2), three from 2nd middling (2GA2, 2GB1, 2GB2), two from 3rd middling (3G1 and 3G2), one each from 4th and 5th middling (4G and 5G) were collected. Straight run flour (STR-1) was also collected for comparison.

Analytical grade reagents, distilled and dry solvents were used throughout the study. Fatty acid standards were procured from Sigma Chemicals, U.S.A.

Extraction of free lipids

Free lipids from the milled streams were extracted according to the AACC, 1995 method[8]. Five grams of each stream (after drying in vacuum oven) were extracted for 4–6 h with petroleum ether (40–60 °C) in a Soxhlet apparatus. The extracted lipid was dried over anhydrous sodium sulphate for 2 h, filtered and remaining solvent was removed by nitrogen flushing. The residue obtained was weighed to determine the yield of free lipid and then dissolved in 1 ml of methylene chloride and stored at −20 °C for further analysis. The residue after extraction of free lipids was used for the determination of bound lipids. Each sample was replicated.

Extraction of bound lipids

Residues of milled streams from after extraction of free lipid as mentioned above were used for determination of bound lipids according to the method of Morrison *et al.*[9] with slight modifications. Samples from different milling streams were shaken with ten volumes of methanol: chloroform (2:1 v/v) for 6–8 h in a shaker. The extracted bound lipids were shaken with half volume of water containing about 50 mg of sodium chloride to remove the water-soluble impurities. The lipid containing organic layer was dried over anhydrous sodium sulphate and excess solvent was evaporated by nitrogen flushing. Finally, the residue was weighed and dissolved in appropriate solvent and stored at −20 °C for further analysis. Each sample was replicated two times.

Preparation of methyl esters

Lipid fractions were converted to methyl esters by sodium methoxide method of J.M. Deman[10].

Fatty acid analysis by gas chromatography (GC)

Fatty acids were quantitatively analysed by gas chromatography (GC) as their methyl esters. GC was performed with a gas liquid chromatography (Shimadzu, Model No. 15 A, Japan) equipped with a flame ionization detector, using 0·5 mm id. × 10 ft column packed with 12·5% DEGS on 60/80 mesh chromosorb column, temperature 180 °C with a temperature programming of injection 220 °C and detection 250 °C. Flow rates of nitrogen (carrier gas), hydrogen and air were kept at 40 mL/min respectively. Peaks were identified by comparing their retention times with those of authentic reference standards (Sigma, U.S.A.). The peaks were integrated by a computing integrator. Figures reported are percent of individual peaks. Duplicates were carried out for each sample.

Table I Mass balance of free and bound lipid content in milled streams

Sample Code	Flour yield (Percentage)	Free lipid content Units	Bound lipid content Units
Break flour			
I BK	8·40	0·0084	0·0168
II BK	8·30	0·0083	0·0332
III BKC	5·20	0·0520	0·0312
IV BK + F	3·70	0·0703	0·0370
GDR	5·90	0·0236	0·0118
III BKF	4·90	0·0931	0·0441
Reduction flour			
IR	8·10	0·0810	0·1053
1GA-1	8·80	0·0880	0·1056
1GA-2	4·40	0·0396	0·0572
1GB-1	6·30	0·0504	0·0945
1GB-2	2·50	0·0250	0·0350
2GA-2	2·70	0·0216	0·0432
2GB-1	7·60	0·0608	0·1140
2GB-2	2·00	0·0160	0·0300
3GI	3·90	0·0351	0·0663
3G2	3·90	0·0312	0·0585
4G	8·30	0·0996	0·1743
5G	5·10	0·0918	0·1020
STR-1 (Calculated)		0·8958	1·1600
STR-1 (Estimated)		0·9000	1·0000

I BK and II BK are First and Second Break passages; II BKC is Third Break Coarse passage.
IV BK + Filter is Fourth Break Filter passage; III BK Fine is Third Break Fine passage.
GDR is Grader passage; IR is Semolina passage; 1GA-1, 1GA-2, 1GB-1 and 1GB-2 are different passages of First middling.
2GA-2, 2GB-1 and 2GB-2 are different passages of Second middling.
3G1 and 3G2 are different passages of Third middling.
4G and 5G are Fourth and Fifth middling passages; STR-1 is Straight Run flour.

RESULTS AND DISCUSSION

Quality characteristics of wheat

The wheat used in the mill had the following quality characteristics on 14% mb: ash, 1·7%; falling number, 395 s; SDS-sedimentation, 47 mL and protein, 10·5%.

Lipid content in flour streams

The data (Fig. 1) indicated an increase in the free lipid content from 0·1 to 1·9% as the grinding progressed from first to fourth break, possibly due to increase in the concentration of germ as well as bran, pericarp and aleurone layer which are rich in lipids[11]. Since in the initial two break passages, grains are opened, most of the flour originates from central portion of endosperm. Therefore, the lipid content is very low (0·1%) in these streams. Similarly, an increasing trend was observed in free lipid content for flour streams in reduction passage systems from 0·9 to 1·8%. This could be due to the release of more lipids from germ as it gets pressed in a series of reduction rolls[2,12]. The bound lipids also increased from 0·2

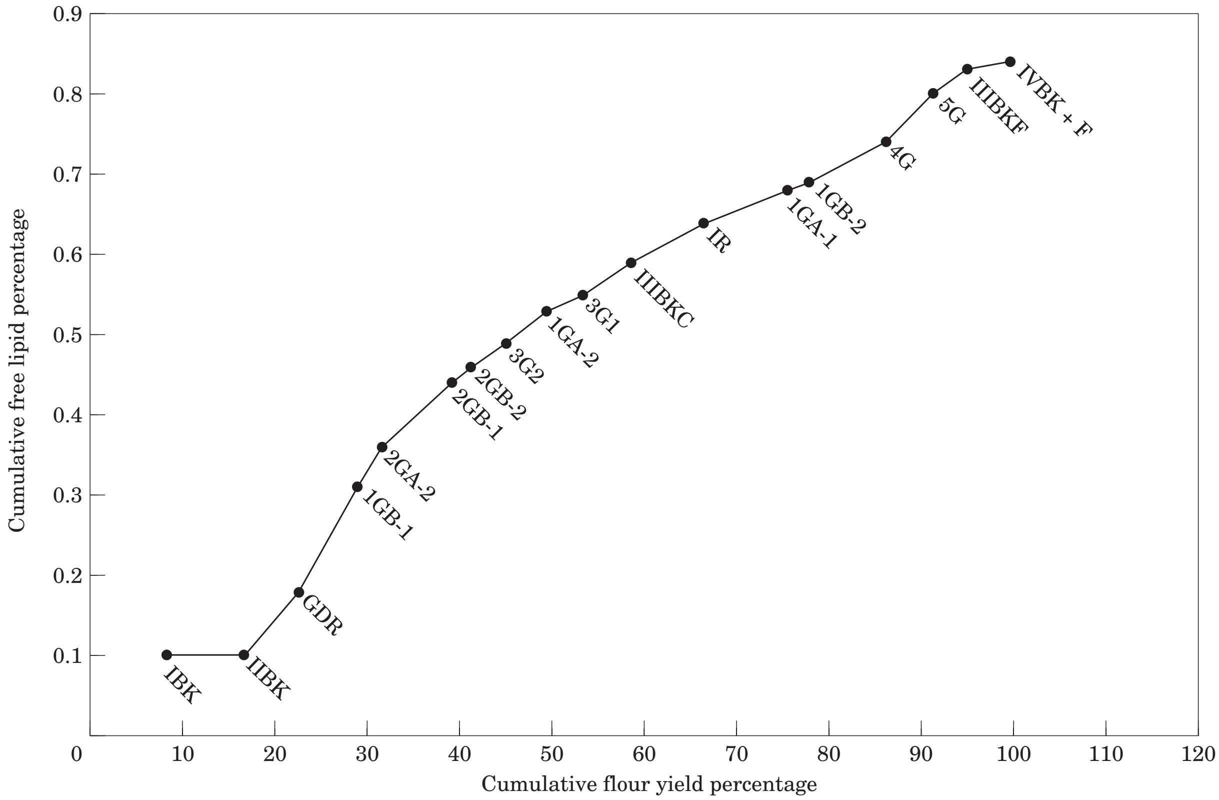

Figure 2 Typical free lipid curve of milled streams.

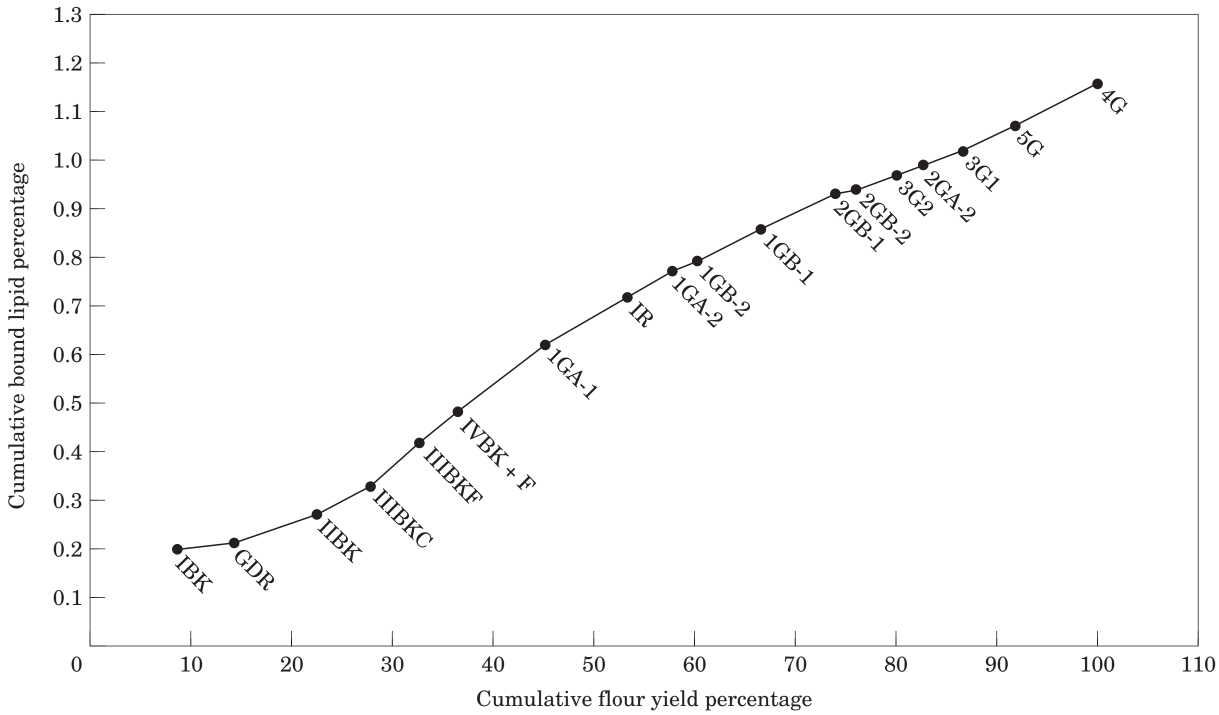

Figure 3 Typical bound lipid curve of milled streams.

Table II Fatty acid composition of free lipids in milled streams

Sample Code	Saturated Fatty Acid[a] (%)		Unsaturated Fatty Acid[a] (%)			Others[a] (%)
	Palmitic Acid (16:0)	Stearic Acid (18:0)	Oleic Acid (18:1)	Linoleic Acid (18:2)	Linolenic Acid (18:3)	
Break flour						
I BK	28·0	ND	29·1	30·0	10·0	3·0
II BK	19·0	ND	18·0	49·0	11·0	3·0
III BKC	7·0	ND	26·0	65·0	1·5	0·5
IV BK + Filter	42·0	2·6	14·8	34·3	2·4	3·9
III BK Fine	18·9	1·0	21·0	52·6	1·6	4·8
GDR	25·0	3·8	27·5	37·5	1·3	5·0
Reduction flour						
IR	23·0	0·8	18·5	49·8	1·5	6·4
1GA-1	21·0	1·1	15·0	53·6	2·5	6·8
1GA-2	23·0	1·2	11·8	53·1	2·0	8·8
1GB-1	16·3	1·3	24·6	52·5	2·0	3·4
1GB-2	18·6	1·1	14·0	59·6	3·7	3·0
2GA-2	18·8	1·3	17·5	55·8	4·4	6·1
2GB-1	17·5	1·0	12·5	58·8	4·9	5·4
2GB-2	16·3	1·1	16·3	55·5	2·4	9·0
3G1	16·7	1·3	15·6	55·6	3·3	7·6
3G2	17·5	1·0	17·5	56·3	3·8	4·0
4G	24·2	1·2	13·3	60·0	3·3	1·0
5G	17·8	1·0	18·3	55·6	3·9	3·4
STR-1	17·7	0·8	13·3	62·2	4·4	1·4

ND: Not detected.
[a] Percentage based on FAME recovery.
I BK and II BK are First and Second Break passages; III BKC is Third Break Coarse passage.
IV BK + Filter is Fourth Break Filter passage; III BK Fine is Third Break Fine passage.
GDR is Grader passage; IR is Semolina passage; 1GA-1, 1GA-2, 1GB-1 and 1GB-2 are different passages of First middling. 2GA-2, 2GB-1 and 2GB-2 are different passages of Second middling. 3G1 and 3G2 are different passages of Third middling.
4G and 5G are Fourth and Fifth middling passages; STR-1 is Straight Run flour.

to 1·0% as grinding progressed from I to IV break while it increased from 1·2 to 2·1% in reduction passage. The last passage of both break (IV Break + Filter) and reduction (5G) passages contained the maximum amount of lipid due to extraction of aleurone layer adhering to bran which contains a higher amount of lipid[2,11–13]. The results indicated that bound lipid content was higher in reduction flour streams, which is also very clear from Figure 1.

The straight run flour had a free and bound lipid content of 0·9 and 1·0% respectively. These values were comparable to calculated values from the sum of lipid content in different streams expressed on percentage of total flour yield (Table I).

Cumulative free and bound lipid content of flour stream against cumulative flour yield are depicted graphically in Figure 2 ('Free lipid curve') and Figure 3 ('Bound lipid curve') respectively. The curves are similar to the well known 'ash curve'. These typical lipid curves enable the miller to select the suitable streams for blending to obtain flours with desired levels of free and bound lipid content.

Fatty acid composition of flour streams

The percentage of fatty acid, present in the milled streams was calculated based on the individual peak areas of corresponding chromatograms and the results were expressed on the basis of flour weight. To allow positive identification of the fatty acid retention time, the standards were run along with the samples.

Table III Fatty acid composition of bound lipids in milled streams

Sample Code	Saturated Fatty Acid[a]		Unsaturated Fatty Acid[a]			Others[a]
	Palmitic Acid (16:0)	Stearic Acid (18:0)	Oleic Acid (18:1)	Linoleic Acid (18:2)	Linolenic Acid (18:3)	
Break flour						
I BK	45·0	6·5	5·5	40·0	ND	3·0
II BK	36·8	3·5	4·8	37·5	8·3	9·3
III BKC	55·5	8·0	3·3	23·8	5·0	4·3
IV BK + Filter	54·8	6·0	8·4	26·0	1·0	3·8
III BK Fine	23·8	1·0	7·2	63·7	1·7	2·4
GDR	16·0	3·5	16·5	40·0	11·5	12·5
Reduction flour						
IR	18·4	1·5	9·0	65·5	2·5	3·1
1GA-1	16·0	1·5	8·5	63·0	5·5	5·5
1GA-2	18·8	6·5	1·5	72·2	0·8	0·2
1GB-1	16·1	1·3	9·3	66·6	2·7	4·3
1GB-2	17·9	1·3	10·8	61·0	3·5	5·6
2GA-2	17·1	1·0	8·3	68·3	2·6	2·8
2GB-1	17·8	3·5	10·5	60·8	3·6	3·7
2GB-2	17·2	3·9	11·9	58·0	5·1	3·8
3G1	19·5	0·6	8·3	64·5	1·8	5·3
3G2	14·2	2·0	6·7	66·5	4·7	5·9
4G	16·2	1·0	11·7	67·5	1·5	2·1
5G	16·9	1·0	17·5	60·0	3·1	1·5
STR-1	17·9	0·9	13·0	57·5	7·2	3·5

ND: Not detected.
[a] Percentage based on FAME recovery.
I BK and II BK are First and Second Break passages; III BKC is Third Break Coarse passage.
IV BK + Filter is Fourth Break Filter passage; III BK Fine is Third Break Fine passage.
GDR is Grader passage; IR is Semolina passage; 1GA-1, 1GA-2, 1GB-1 and 1GB-2 are different passages of First middling. 2GA-2, 2GB-1 and 2GB-2 are different passages of Second middling. 3G1 and 3G2 are different passages of Third middling.
4G and 5G are Fourth and Fifth middling passages; STR-1 is Straight Run flour.

Free lipid

The fatty acid composition of free lipids are given in Table II. Among the saturated fatty acids, palmitic acid was predominant in break flour streams. The highest content of 42% palmitic acid was found in IV Break filter. The amount of stearic acid present in the initial three break systems was not detectable while a low amount was present in the IV Break filter and III Break fine also in reduction flour streams palmitic acid was predominant among the saturated fatty acids, ranging from 16·3 to 24·2%. Among the unsaturated fatty acids, linoleic acid was the predominant acid in the III Break coarse possibly due to germs and bran portions of wheat present in these passages[2,11–13].

In reduction flour streams, there is little difference in the unsaturated fatty acid content except in the 4th and 5th middling passages. Oleic acid ranged from 11·8 to 18·5% while linoleic acid ranged from 49·8 to 60·0%. However, the 4th middling has a higher content of 60% linoleic acid due to more of germ coming into this middling passage. The fatty acid composition of straight run flour is in the range of reported data[14].

Bound lipids

The fatty acid composition of bound lipids is given in Table III indicated that the trend remained similar to free lipids. However, the actual content of fatty acids is different. Even here, the palmitic acid content was higher in the III Break coarse among the Break passages and in the 3rd and 4th middling among the reduction passages. In general, the saturated fatty acid content is greater in break streams. As in free lipids, the linoleic acid content is more among the bound lipids. In general, the level of any of the unsaturated fatty

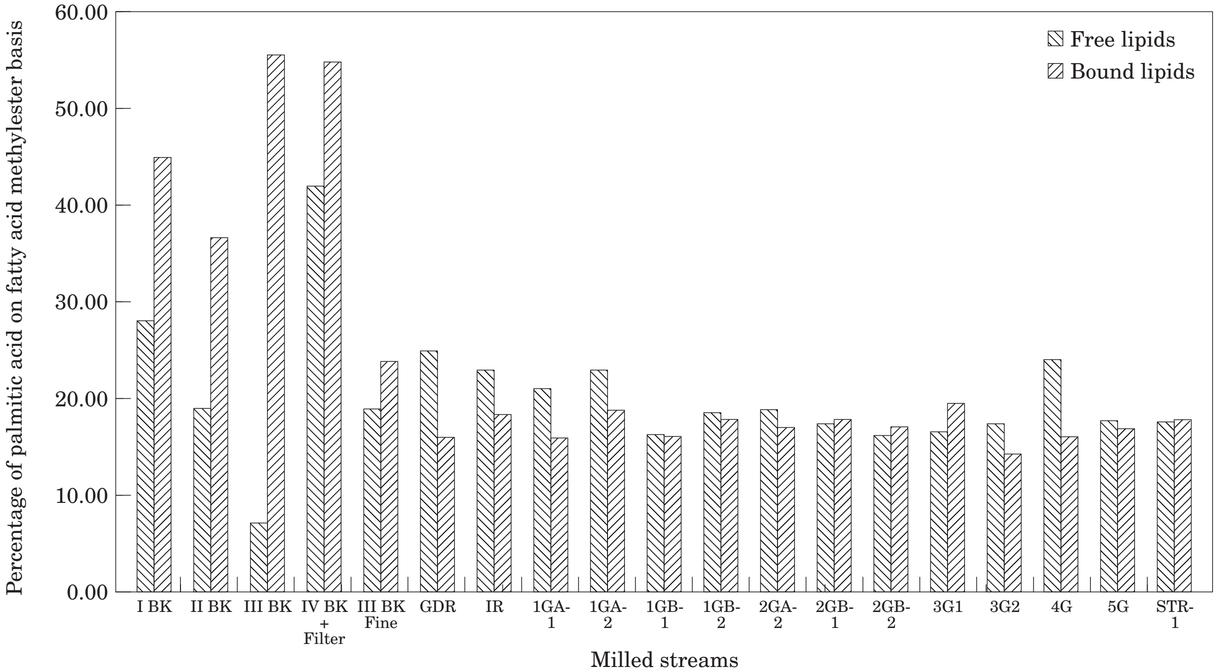

Figure 4 Comparison of palmitic acid content in free and bound lipids of milled streams.

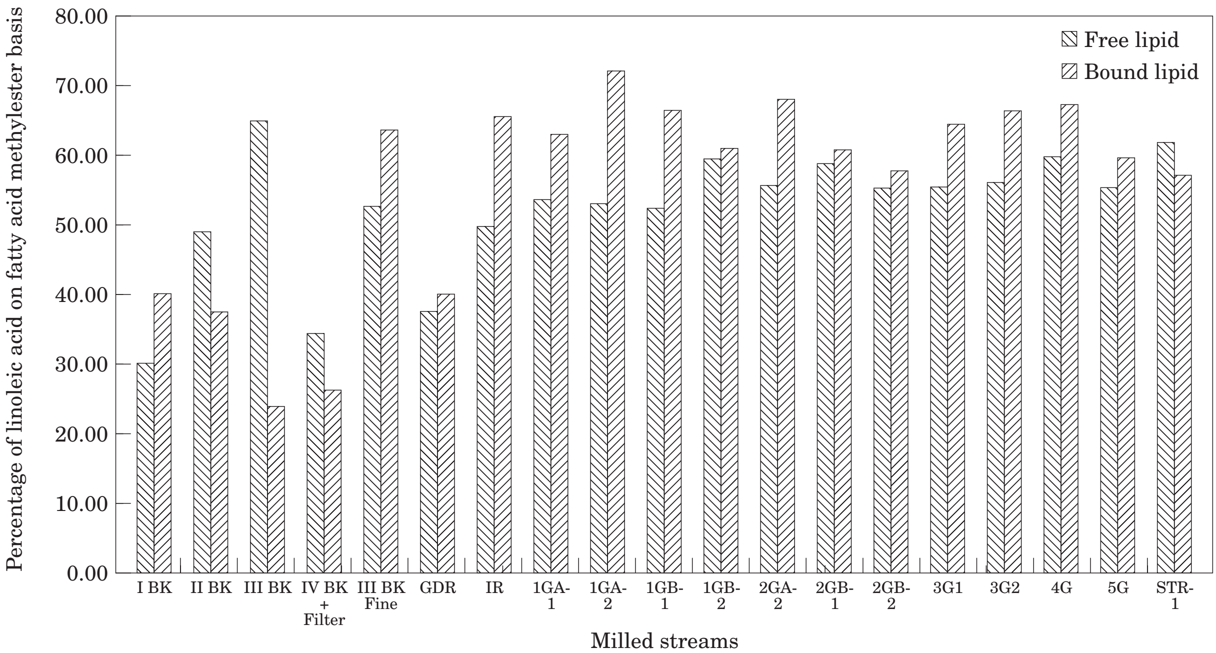

Figure 5 Comparison of linoleic acid content in free and bound lipids of milled streams.

acid among reduction streams was higher in bound lipids when compared to free lipids. The 1st and 4th middlings among reduction streams and III Break fine had the maximum level of linoleic acid.

Figures 4 and 5 clearly indicated that the amount of palmitic and linoleic acids present in initial Break streams of bound lipids is higher in comparison to that present in free lipids. However, the level of palmitic acid is higher in flour from IV Break filter in bound lipid than that of free lipid, whereas linoleic acid content is higher in flour from III Break coarse in free lipid than that of bound lipid. Among the reduction flour streams, bound lipids obtained from most of the milled streams have a higher content of these two fatty acids when compared with that present in free lipids.

CONCLUSION

Lipid content and its fatty acid composition of various flour streams of commercially milled samples indicated that reduction flour streams have a greater percentage of bound lipids. Palmitic acid and linoleic acid were the predominant fatty acids in both free and bound lipids. Maximum levels of palmitic acid were found in IV Break filter, III Break coarse, 3rd and 4th middling whereas the linoleic acid content was found to be higher in III Break coarse, III Break fine, 1st and 4th middling among the streams in both free and bound lipids.

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REFERENCES

1. Kent, N.L. In 'Technology of Cereals with Special Reference to Wheat'. Pergamon Press, New York (1978).
2. Pomeranz, Y. In 'Wheat Chemistry and Technology' Vol. I & II. American Association of Cereal Chemists, St. Paul., Minnesota (1988).
3. Addo, K. and Pomeranz, Y. Effects of lipids and emulsifiers on alveograph characteristics. *Cereal Chemistry* **69** (1992) 6–12.
4. Bekes, F., Zawistowska, V., Zillman, R.R. and Bushuk, W. Relationship between lipid content and composition and loaf volume of twenty-six common spring wheat. *Cereal Chemistry* **63** (1986) 327–331.
5. Mc Cirnack, G., Panozzo, J. and Mac Ritchie, F. Contributions to bread making of inherent variations in lipid content and composition of wheat cultivators. II. Fractionation and reconstitution studies. *Journal of Cereal Science* **13** (1991) 263–274.
6. Chung, O.K., Pomeranz, Y. and Finney, K.F. Relation of polar lipid content to mixing requirement and loaf volume potential of hard red wheat flour. *Cereal Chemistry* **59** (1982) 14–20.
7. Morrison, W.R. and Panpaprai, R. Oxidation of free and esterified linoleic and linolenic acids in bread doughs by wheat and soya lipoxygenases. *Journal of Science Food and Agriculture* **26** (1975) 1225–1236.
8. Approved Methods of the American Association of Cereal Chemists American Association of Cereal Chemists Inc., St. Paul, Minnesota, U.S.A. (1995).
9. Morrison, W.R., Tan, S.L. and Haargin, K.D. Methods of quantitative analysis of lipids in cereals grains and similar tissues. *Journal of Science Food and Agriculture* **31** (1980) 329–340.
10. Deman, J.M. Determination of the fatty acid composition of milk fat by dual column temperature programmed gas-liquid chromatography. *Journal of Dairy Science* **47** (1964) 546–547.
11. Morrison, W.R. and Hargin, K.D. Distribution of soft wheat kernel lipids into flour milling fractions. *Journal of Science Food and Agriculture* **32** (1981) 579–587.
12. Morrison, W.R., Coventry, A.M. and Barnes, P.J. The distribution of acyl lipids and tocopherols in flour mill streams. *Journal of Science Food and Agriculture* **33** (1982) 925–933.
13. Morrison, W.R. and Barnes, P.J. Distribution of wheat acyl lipids and tocols in mill streams. In 'Lipids in Cereal Technology' (P.J. Barnes, ed.). Academic Press, London (1983) pp 149–164.
14. Nelson, J.H., Glass, R.L. and Geddes, W.F. The triglycerides and fatty acids of wheat. *Cereal Chemistry* **40** (1963) 343–350.