IMPROVED QUALITY OF BAKED PRODUCTS BY RICE BRAN OIL

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ABSTRACT

Baking is a developing industry in Pakistan, which is growing in size. The people are becoming more conscious about their health and nutrition. Foods that are convenient, with good taste, reasonably priced and superior in quality are in great demand. Rice bran oil (RBO) was applied into baked products such as cookies at various levels i.e. 0, 25, 50, 75 and 100% by gradually replacing normal shortening to improve the quality of cookies in term of shelf life due to natural antioxidants present in RBO. Five treatments of RBO and normal shortening (NS) were used to prepare cookies and 45 days storage study was conducted to investigate improvement in shelf life. Statistical analysis regarding chemical characteristics of cookies indicated that both treatments and storage have highly significant effect on moisture content, fat content and NFE content of cookies while ash content and crude fiber showed non-significant change. Storage has also significant effect on protein content of cookies but it remains unaffected by changing treatments. During 45 days storage moisture content, protein content, fat content and NFE content decreases significantly. The thiobarbituric acid number (TBA no.) was calculated after each storage interval (fortnightly). Both treatments and storage showed significant effect on TBA no. of cookies. Treatment T_5 (100% RBO) exhibited TBA no. (0.03) while T_1 (100%NS) showed (0.05) mg of malenaldehyde/Kg at 0 day. There was an increase in TBA no. during storage But Treatment T_5 (100%RBO) showed the minimum increase (0.05) followed by T_4 (0.06) and T_3 (0.08). Based on the results of proximate analysis, sensory evaluation and TBA number, it is concluded that by increasing the percentage of rice bran oil (RBO), the TBA number decreases and the on set of rancidity is delayed. Moreover the present study suggests that T_3 (50%RBO + 50%NS) can produce superior quality cookies to prove effectiveness of RBO as bakery shortening.

KEY WORDS: Rice bran oil, improved quality, cookies, storage, sensory attributes, shelf life, TBA no.

INTRODUCTION

RBO is generally considered to be one of the highest quality vegetable oil in terms of its cooking quality, shelf life and fatty acid composition (Sayre and Sunders, 1990). Rice bran oil is miracle product obtained from the outer brown layer of rice. Generally rice bran contains 15 % to 20 % oil (Marshall and Wadsworth, 1994). It is extensively used in Japan, Korea, China, Taiwan and Thailand as a "Premium Edible Oil". In Japan, Rice Bran Oil is more popularly known as a "Heart Oil'. In Western countries Rice Bran Oil has acquired the status of a "Health Food". The oryzanol present in rice bran is reported to have functions similar to vitamin E in promoting growth, facilitating capillary growth in the skin, and improving blood circulation along with stimulating hormonal secretion (Luh *et al.*, 1991). Rice bran oil is an excellent source of PUFA which are helpful in lowering cardiovascular risks. Rice bran oil lowered human blood cholesterol more effectively than did sunflower, corn and safflower oils (Suzuki and Oshima, 1962). RBO is superior cooking oil and is used in the manufacture of mayonnaise and salad dressings (Swern, 1972). Rice bran oil is an excellent cooking medium because it is nutritionally superior, contains more micronutrients, longer shelf life, more stable at higher temperature, gives better taste & flavor to food items, frying takes less time so saves energy and economical due to 15% less absorption of oil during frying (Sharma, 2002). Rogers *et al.* (1993) also reported the levels of these nutritionally significant components (tocopherols, tocotrienols and oryzanols) in rice bran oil.

Kirk and Sawyer (1999) investigated that refined oil in good condition has TBA value of 0.02-.08 where as crude oil or badly stored oils have 0.1-0.2. Furia (1968) reported a commercial test based on the reaction of 2-thiobarbituric acid with the oxidation products of fats & oils to form a red color. Edward (1985) used Thiobarbituric acid combined with glacial acetic acid to develop a color in extract of meat and meat products that will establish TBA number, defined as melonaldehyde, which determined the oxidative rancidity level. Kim *et al.* (2000) added 2% RBO to restructured beef

roasts and concluded that beef roasts containing RBO had higher oxidative stability ($P<0.05$) during storage at 4 ^{o}C than did beef roasts without additives (control). Joo *et al.* (2001) investigated effects of rice bran oil on the oxidative stability and nutritional properties of restructured beef roasts and concluded that addition of 2% rice bran oil (w/w) is effective in improving both oxidative stability and vitamin E levels of restructured beef roasts.

The baking is a developing industry in Pakistan which is growing in size. The people are becoming more conscious about their health and nutrition. Foods that are convenient, with good taste, reasonably priced and carry a favorable nutritional image are in great demand. Among bakery products especially cakes & cookies, fat is one of the major ingredients. The functional and nutritional properties of RBO has appeared well suited to its usage as shortening in baked goods like cookies.

The present project is designed to achieve the following objectives.

1) To evaluate role of RBO in quality improvement of bakery products with extension in shelf life
2) To evaluate the suitability of RBO in baked products like cookies

MATERIALS AND METHODS

A i. Procurement of Raw Material

Raw material including wheat flour, sugar, shortening, eggs & baking powder were procured from local market. Rice bran oil was taken from Institute of Food Science & Technology.

ii. Preparation of Cookies

Cookies were prepared with some modifications according to method given in AACC (2000). In the formation of cookies, shortening was used according to ratios as mentioned in Table 1.

B. Chemical Analysis

The packed cookies, prepared from different levels of shortening, were placed at room temperature and storage studies for moisture, crude protein, crude fat, crude fiber, ash and NFE contents of cookies were conducted fortnightly for 45 days according to the methods described in AACC (2000).

C. Sensory Evaluation

The cookies were evaluated by a panel of judges from the staff & postgraduate students of Institute of Food Science & Technology for taste, color, flavor, texture, crispness and overall acceptability at 0, 15, 30 and 45 days interval of storage according to the procedure described by Meilgaard *et al.* (1991).

D. Thiobarbituric Acid Number (TBA no.)

To assess the development of rancidity in the product, TBA no. of cookies stored at stated intervals was determined fortnightly as described by Kirk and Sawyer (1991).

TBA no. (As mg malenaldehyde per Kg sample) = 7.8 x D

E. Statistical Analysis

The data obtained for each parameter was subjected to statistical analysis to determine the level of significance according to the methods described by Steel *et al.* (1997).

Table 1. Different Treatments Used In Study

Treatments	Normal Shortening (%)	RBO (%)
T_1	100	-
T_2	75	25
T_3	50	50
T_4	25	75
T_5	-	100

T_1 = 100% Normal Shortening (NS) T_2 = 75% NS + 25% RBO T_3 = 50% NS + 50% RBO
T_4 = 25% NS + 75% RBO T_5 = 100% Rice Bran Oil (RBO)

RESULTS AND DISCUSSIONS

A. Chemical Analysis of Cookies

The cookies were prepared by replacing normal shortening with different levels of RBO and stored in polyethylene bags for 45 days. Statistical analysis regarding chemical characteristics of cookies indicated that both treatments and storage have highly significant effect on moisture content, fat content and NFE content of cookies while ash content and crude fiber showed non-significant change. Storage has also significant effect on protein content of

cookies but it remains unaffected by changing treatments. (Table 2). During 45 days storage moisture content, protein content, fat content and NFE content decreases significantly.

Average moisture contents were 1.26, 1.09, 1.18, 1.02 and 1.26% for T_1, T_2, T_3, T_4 and T_5 respectively (Table 3). The highest moisture content 1.26% was found both in T_1 and T_5 followed by 1.18% in T_3 and the lowest 1.02% was found in T_4 followed by 1.09% in T_2. Means for moisture content of cookies explicit significant differences among the treatments.

The mean values for treatments exhibit that T_1, T_3 andT_5 showed non-significant effect with each other but varied significantly from T_4. T_2 explicit the highest ash content 0.71% and the lowest 0. 66% was found in T_5. The data regarding crude protein of cookies showed that average protein contents were 7.90, 7.89, 7.91, 7.88 and 7.90% for T_1, T_2, T_3, T_4 and T_5 respectively. The highest protein content 7.91% was found in T_3 followed by 7.90% in T_1 and $T_5$where as the lowest 7.88% was found in T_4 followed by 7.89% in T_2 . Replacement of RBO resulted in increases of fat content. The maximum value for fat content was noted in T_5 (100% RBO). Average fat contents were 21.70, 21.81, 21.81, 21.82 and 21.83% for T_1, T_2, T_3, T_4 and T_5 respectively. The maximum value for fat content 21.83% was observed in (T_5) with only RBO which gradually decreased as the proportionate of normal shortening increased in cookies where as the lowest 21.70% was found in T_1 (100% normal shortening) . It is evident from means for fat content that treatments differ significantly with each other. Results pertaining crude fiber content of cookies (Table 3) showed that treatments exhibit non-significant differences with each other. Average fiber contents were 0.22, 0.19, 0.17, 0.20 and 0.20 % for T_1, T_2, T_3, T_4 and T_5 respectively. The highest fiber content 0.22% was found in T_1 and the lowest 0. 17% was found in T_3. T_2, T_4 and T_5 got almost same fiber content. NFE was estimated by difference method and is presented in Table (3). Average NFE contents were 68.22%, 68.44%, 68.21%, 68.40% and 68.15% for T_1, T_2, T_3, T_4 and T_5 respectively. The highest NFE content 68.44% was found in T_2 followed by 68.40% in T_4 and the lowest 68.15% was found in T_5 followed by 68.21% in T_3.

During 45 days storage moisture content increased in all the cookies and caused significant changes (Table 5). In freshly prepared cookies, it varies from 0.67-0.95% which increased to 1.35-1.77% after 45 days of storage. At 0 day, the mean moisture content for all the treatments was 0.81% which increased 1.03%, 1.24 % and 1.57% after 15, 30 and 45 days storage respectively. This phenomenon of moisture absorption during storage is also supported by Wade (1988), Leelavathi and Rao (1993), Rao *et al*., (1995) and Pasha (2001). Storage has non-significant on ash content of cookies. At 0 day, the mean ash content for all the treatments was 0.74% which decreased non-significantly to 0.64% after 45 days storage due to increase in moisture content absorbed from the atmosphere. A non-significant decreasing trend in ash content of legume fortified biscuits due to moisture absorption was executed by Ahmad (1996). Similar findings are reported by Akbar (2000), Pasha (2001) and Malik (2001). Storage has significant effect on protein content of cookies. In freshly prepared cookies, protein content varies from 7.93-7.99% which decreased to 7.80-7.86% after 45 days of storage. At 0 day, the mean protein content for all the treatments was 7.96% which decreased significantly to 7.92%, 7.86 % and 7.83% after 15, 30 and 45 days storage respectively. This decrease in protein content during storage was due to the incorporation of moisture in cookies from the atmosphere. Fat content is also affected by storage period. In freshly prepared cookies, fat content varies from 21.82-21.89% which decreased to 21.50-21.78% after 45 days of storage. At 0 day, the mean fat content for all the treatments (average of 5 treatments) was 21.85% which decreased to 21.83%, 21.78 % and 21.70% after 15, 30 and 45 days storage respectively. It is evident from the results that there is significant difference in fat content of cookies after every 15 days of storage. This decrease in fat content during storage was due to the incorporation of moisture in biscuits from the atmosphere and due to oxidation of fatty acids resulting in free fatty acid formation. Means for fiber content showed non-significant effect of storage after every 15 days. At 0 day, the mean fiber content for all the treatments was 0.26% which decreased non-significantly to 0.16% after 45 days storage due to increase in moisture content absorbed from the atmosphere. A non-significant decreasing trend in fiber content of legume fortified biscuits due to moisture absorption was executed by Ahmad (1996). Storage has significant effect on NFE in all the samples. In freshly prepared cookies, NFE content varies from 68.23-68.56% which decreased to 68.06-68.29% after 45 days of storage. Means for NFE revealed that there is

significant decrease in the NFE content of cookies after every 15 days of storage. At 0 day, the mean NFE for all the treatments was 68.38% which decreased 68.30%, 68.29% and 68.10% after 15, 30 and 45 days storage respectively.. Malik (2001) also described the same trend of decreasing NFE of cookies during storage.

B. Thiobarbituric Acid Number (TBA NO.)

To assess the development of rancidity in the product, the thiobarbituric acid value (TBA no.) was calculated after each storage interval. Analysis of variance (Table 2) showed that both treatments and storage have significant effect on TBA no. of cookies.

Average TBA values were 0.08, 0.06, 0.05, 0.04 and 0.03 for T_1, T_2, T_3, T_4 and T_5 respectively (Table 3). Treatment T_5 (100% RBO) exhibited TBA no. (0.03) while T_1 (100%NS) showed (0.05) mg of malenaldehyde/Kg at 0 day. There was an increase in TBA no. during storage (Table 4). T_5 (100%RBO) showed the minimum increase (0.05) followed by T_4 (0.06) and T_3 (0.08). It is evident from the results that by increasing the percentage of rice bran oil (RBO), the TBA number decreases and the on set of rancidity is delayed as shown in Figure 1.

It is certainly due to the tocopherols, tocotrienols, and oryzanols in RBO that act as natural antioxidants (Lloyd *et al.*, 2000). Rogers *et al.* (1993) also reported the levels of these nutritionally significant components (tocopherols, tocotrienols and oryzanols) in rice bran oil. RBO based products have extended shelf life since RBO is extremely stable against the onset of rancidity and oxidative deterioration. During storage, there was increase in TBA value but the treatment T_1 (without RBO) showed maximum increase. Treatments containing RBO also shows some increase in TBA value but it was within limits. Kirk and Sawyer (1999) investigated that refined oil in good condition has TBA value of 0.02-0.08 where as crude oil or badly stored oils have 0.1-0.2.

Table 2. Analysis of variance chemical composition and TBA no. of cookies.

Source	df	Moisture %	Ash %	Protein %	Fat %	Fiber %	NFE %	TBA no.
Storage (S)	3	50.98**	2.75 ^{NS}	87.49**	126.45**	2.71 ^{NS}	220.31**	29.11**
Treatment (T)	4	4.42**	2.72 ^{NS}	2.72 ^{NS}	64.06**	0.31 ^{NS}	539.16**	24.30**
S x T	12	1.09^{NS}	0.01 ^{NS}	2.56 ^{NS}	13.22**	0.03 ^{NS}	38.49**	1.61 ^{NS}
Error	40							
Total	59							

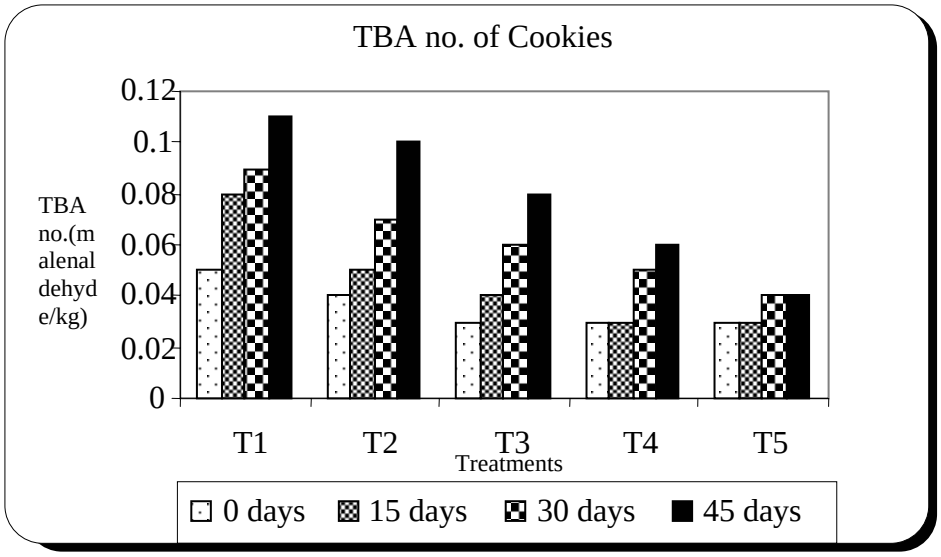
Table 3. Effect of different treatments on chemical composition and TBA no. of cookies.

Treatments	Moisture content (%)	Ash content (%)	Protein content (%)	Fiber content (%)	Fat content (%)	NFE (%)	TBA no.
T_1	1.26 a	0.70	7.90	0.22	21.70 b	68.22 c	0.08 a
T_2	1.09 bc	0.71	7.89	0.19	21.81 a	68.44 a	0.06 b
T_3	1.18 ab	0.70	7.91	0.17	21.81 a	68.21 c	0.05 c
T_4	1.02 c	0.68	7.88	0.20	21.82 a	68.40 b	0.04 cd
T_5	1.26 a	0.66	7.90	0.20	21.83 a	68.15 d	0.03 d

Table 4. Effect of Storage (days) on chemical composition and TBA no. of cookies.

Days	Moisture content (%)	Ash content (%)	Protein content (%)	Fiber content (%)	Fat content (%)	NFE (%)	TBA no.
0	0.81 d	0.74	7.96 a	0.26	21.85 a	68.38 a	0.04 d
15	1.03 c	0.72	7.92 b	0.20	21.83 b	68.30 b	0.05 c
30	1.24 b	0.66	7.86 c	0.17	21.78 c	68.29 c	0.06 b
45	1.57 a	0.64	7.83 d	0.16	21.70 d	68.10 d	0.08 a

Fig. 1 Effect of different treatments and storage period on Thiobarbituric acid Value (TBA no.) of cookies.



D. Sensory Evaluation of Cookies

The sensory evaluation is very important criterion in food industry. The cookies prepared from commercial wheat flour with different levels of RBO as shortening were stored in polyethylene bags and placed in laboratory shelf at ambient temperature for 45 days. These were evaluated for various sensory attributes fortnightly upto 45 days storage. Analysis of variance explicit that cookies differed significantly regarding various sensory attributes like color, taste, flavor, crispness, texture and overall acceptability, due to treatments and storage as shown in Table 5. The results regarding each sensory attribute are discussed one by one.

Treatments have significant effect on color of cookies (Table. 6). T_3 got maximum score (7.77) while T_5 obtained the lowest score (6.32). T_4 and T_1 got fairly high score which showed that T_3 (50% RBO + 50% NS) was preferred by the judges because it gave the desired color to the cookies which distinguished it from others, yet T_4 and T_1 were also acceptable. Judges placed T_3 (7.30) at the first position and T_5 (6.25) at the last position, when averaged over all means for flavor of cookies. T_4 (7.05) was also favored by the judges. Taste of cookies showed highly significant differences among the treatments. Judges ranked T_3 (7.77) at the first position and T_5 (6.20) at the last position, when averaged over all means. The quality score in response to crispness of the cookies depicted that T_3 got maximum score (7.20) while T_5 obtained the lowest score (6.25). T_3 and T_4 got fairly high score which showed that T_3 (50% replacement with normal shortening) was preferred by the judges because it gave the desired crispness to the cookies which distinguished it from others. The results concerning with the score for texture of cookies disclosed a highly significant difference among treatments. T_3 got the maximum score 7.15 while T_5 was at the bottom obtaining 6.47 score. Overall acceptability was determined on the basis of quality scores obtained from the evaluation of color, taste, flavor, texture and crispness of the cookies. T_3 got the maximum score 7.44 while T_5 was at the bottom obtaining 6.33 score.

Storage has significant effect on color of cookies. (Table. 7)The maximum score 7.30 (Average of 5 treatments) was obtained at 0 days by all the cookies which was significantly decreased as the storage increased. The minimum score of 6.54 (average of 5 treatments) was obtained at 45 days storage. The deterioration in color of biscuits might be due to the absorption of moisture from the atmosphere and oxidation of fats. These results are in close agreement with the findings of Ahmad (1993), Elahi (1997), Pasha (2001) and Iftikhar (2002). Flavor of cookies disclosed that maximum score was obtained by fresh cookies (0 days) which was gradually decreased with storage days. The range between 0 days and 45 days was 6.50 - 7.32. The loss in flavor might be attributed to absorption of water that resulted in fat oxidation. As regarding taste of cookies, maximum score was obtained by fresh cookies (0 days) which

was gradually decreased with storage days. The range between 0 days and 45 days was 6.62 - 7.36. Elahi (1997) also found a decrease in mean score for taste from 6.62-5.81 after 90 days storage in biscuits prepared from composite flour. The quality score in response to crispness of the cookies depicted that maximum score 7.08 (Average of 5 treatments) was obtained all the fresh cookies (0 days) which was decreased significantly as the storage increased. The minimum score of 6.28 (average of 5 treatments) was obtained at 45 days. The range between 0 day and 45 days was 6.28 -7.08. Wade (1988) stated that the biscuits last their crispness during storage due to moisture absorption. The results concerning with the score for texture of cookies disclosed maximum score was obtained by fresh cookies (0 day) which was gradually decreased with storage days. The range between 0 day and 45 days was 6.26-7.08. Ahmad (1993) reported that texture of fresh biscuits was better than the stored ones. Overall acceptability was determined on the basis of quality scores obtained from the evaluation of color, taste, flavor, texture and crispness of the cookies. Analysis of variance disclosed a highly significant effect of storage on overall acceptability of cookies. As a whole the maximum score was obtained by fresh cookies (0 days) which gradually decreased with storage days. The range between 0 days and 45 days was 6.45-7.24. In earlier studies, a gradual decrease in overall acceptability of biscuits during storage was reported by Elahi (1997) who attributed it to moisture absorption, increase in peroxide value and free fatty acid contents in biscuits.

Table 5. Analysis of variance sensory attributes of cookies.

Source	df	color	taste	flavor	crispness	texture	Overall acceptability
Storage (S)	3	32.33**	37.57**	23.73**	12.40**	88.32**	46.13**
Treatment (T)	4	72.44**	85.06**	26.33**	9.00**	46.93**	51.76**
S x T	12	1.92 ^{NS}	1.22 ^{NS}	1.91 ^{NS}	1.73 ^{NS}	1.47 ^{NS}	0.69 ^{NS}
Error	40						
Total	59						

Table 6. Effect of different treatments on variance sensory attributes of cookies

Treatments	Color	Taste	Flavor	Crispness	texture	Overall acceptability
T_1	6.80 c	7.10 b	6.95 b	6.50 b	6.47 c	6.76 c
T_2	6.40 d	6.82 c	6.55 c	6.40 b	6.55 c	6.55 d
T_3	7.77 a	7.77 a	7.30 a	7.20 a	7.15 a	7.44 a
T_4	7.20 b	7.20 b	7.05 b	6.95 a	6.92 b	7.04 b
T_5	6.32 d	6.20 d	6.25 d	6.25 b	6.47 c	6.33 e

Table 7. Effect of Storage (days) on variance sensory attributes of cookies

Days	Color	Taste	Flavor	Crispness	texture	Overall acceptability
0	7.30 a	7.36 a	7.32 a	7.08 a	7.08 a	7.24 a
15	7.10 b	7.24 a	6.80 b	6.96 a	6.96 b	7.01 b
30	6.66 c	6.86 b	6.66 c	6.32 b	6.56 c	6.59 c
45	6.54 c	6.62 c	6.50 c	6.28 b	6.26 d	6.45 c

CONCLUSION

It is evident from the result that by increasing the percentage of rice bran oil (RBO), the TBA number decreases and the on set of rancidity is delayed. Moreover the present study suggests that T_3 (50%RBO + 50%NS) can produce superior quality cookies to prove effectiveness of RBO as bakery shortening.

REFERENCES

AACC. (2000). Approved Methods of American Association of Cereal Chemists. The American Association of Cereal Chemists, Inc. St. Paul. Minnesota.

Ahmad M. (1993). Effect of supplementation of treated moth beans on the quality of biscuits. M. Sc. Thesis, Department of Food Technology, University of Agriculture, Faisalabad. Pakistan.

Ahmad R. (1996). Physico-chemical and biological evaluation of protein enriched biscuits using wheat soy blends. M. Sc. Thesis, Department of Food Technology, University of Agriculture, Faisalabad. Pakistan.

Akbar F. (2000). Nutritious cookies with the addition of peanuts. M. Sc. Thesis, Department of Food Technology, University of Agriculture, Faisalabad. Pakistan.

Edward, S. K. (1985). *Hand book of meat Analysis*. New Jursey: Avery Publishing Co. Wayne,

Elahi H. H. (1997). Use of emulsifies in the production of biscuits from composite flour. M. Sc. Thesis, Department of Food Technology, University of Agriculture, Faisalabad. Pakistan.

Furia T. S. (1968). The Hand Book of Food Additives. Ohio: The Chemical Rubber Co.

Iftikhar M. (2002). Preparation and quality evaluation of cookies containing sweet potato flour. M. Sc. Thesis, Department of Food Technology, University of Agriculture, Faisalabad. Pakistan.

Joo S. K, Godber J. S, King J. M and Prinyawiwatkul W. (2001). Inhibition of cholesterol autoxidation by the non-saponifiable fraction in rice bran in an aqueous model system. Journal of the American Oil Chemists' Society 78 (7): 685-689.

Kim J. S, Godber J. S and Prinaywiwatkul W. (2000). Restructured beef roasts containing rice bran oil and fiber influences cholesterol oxidation and nutritional profile. Journal of Muscle Foods 11 (2): 111-127.

Kirk R. S. and Sawyer R. (1991). Pearson's Composition and Analysis of Foods. 9th edition. Harlow: AWL.

Leelavathi K. and Rao P. H. (1993). Development of high fiber biscuits using wheat bran. Journal of Food Science and Technology 30 (3): 187-190.

Lloyd B. J., Siebenmorgen T. J. and Beers K. W. (2000). Effects of commercial processing on antioxidants in rice bran. Cereal Chemistry 77 (5): 551-555.

Luh B. S, Barber S. and Benedito de Barber C. (1991). Rice bran: chemistry and technology, rice production and utilization. In: Luh, B. S. (ed.). New York: Van Nostrand Reinhold.pp.313.

Malik M. A. (2001). Effect of emulsifiers on the quality of cakes and cookies. M. Sc. Thesis, Department of Food Technology, University of Agriculture, Faisalabad. Pakistan.

Marshall W. E. and Wadsworth J. I. (1994). Rice science and technology. New York: Marcel Dekker, Inc.

Meilgaard D., Civille G.V. and Carr B. T. (1991). Sensory evaluation techniques. 2nd ed. Boca Katon FL: CRC Press.

Pasha I. (2001). Use of dietetic sweeteners in cakes and cookies. M. Sc. Thesis, Department of Food Technology, University of Agriculture, Faisalabad. Pakistan.

Rao T. S. S., Ramanuja M. N., Ashok N. and Vibhaker H. S. (1995). Storage properties of whole egg powder incorporated biscuits. Journal of Food Science and Technology 32 (6): 470-476.

Rogers E. J., Rice S. M., Nicolosi R. J., Carpenter D. R., McClelland C. A. and Romanczyk L. J. (1993). Identification and quantitation of gamma-oryzanol components and simultaneous assessment of tocols in rice bran oil. Journal of the American Oil Chemists' Society 70 (3): 301-307.

Sayre R. N. and Saunders R. M. (1990). Rice bran and rice bran oil. Lipid Technology 2:72.

Sharma A. R. (2002). Edible rice bran oil - consumer awareness programme. Rice bran oil promotion committee. Solvent Extractors Association of India, Mumbai.

Steel R. G. D., Torrie J. H. and Dickey D. (1997). Principles and Procedures of Statistics. A biometrical approach. 3rd ed. New York: McGraw Hill Book Co. Inc.

Suzuki S. and Oshima S. (1962). Influence of blending oils on human serum cholesterol-rice bran oil, safflower and sunflower oil. Journal of Nutrition 28: 194.

Swern O. (1972). Bailey's Industrial Oil and Fat Products. 3rd ed. Inter. Sci. Pub. pp. 196 & 225.

Wade P. (1988). Biscuits, cookies and crackers. In: the principle of craft. London: Elsevior Applied Science.