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ORIGINAL ARTICLE

Preparation of food supplements from oilseed cakes

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Abstract Oilseed cakes have been in use for feed preparation. Being rich in proteins, antioxidants, fibers, vitamins and minerals, oilseed cakes have been considered ideal for food supplementation. These oilseed cakes can be processed and made more palatable and edible by suitable treatments and then incorporated as food supplements for human consumption. Rice bran pellets (RBP), stabilized rice bran (SRB), coconut cake (CC) and sesame cake (SC) were taken up for the study. These were mixed with distilled water and cooked in such a way to separate the cooked solid residue and liquid extract followed by freeze drying to get two products from each. The raw, cooked dried residue and extract were analyzed for various parameters such as moisture (0.9–27.4 %), fat (2.1–16.1 %), ash (3.3–9.0 %), minerals (2.6–633.2 mg/100 g), total dietary fiber (23.2–58.2 %), crude fiber (2.7–10.5 %), protein (3.2–34.0 %), and the fat further analyzed for fatty acid composition, oryzanol (138–258 mg/100 g) and lignan (99–113 mg/100 g) contents and also evaluated sensory evaluation. Nutritional composition of products as affected by cooking was studied. The cooked products (residue and extract) showed changes in nutrients content and composition from that of the starting cakes and raw materials, but retained more nutrients in cooked residue than in the extract. The sensory evaluation of cooked residue and extract showed overall higher acceptability by the panelists than the starting cakes and raw materials. On the basis of these findings it can be concluded that these cooked residue and extract products are highly valuable for food supplementation than the raw ones.

Keywords Rice bran · Copra cake · Sesame cake · Residue · Extract

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Introduction

Oil seeds are second only to grain crops in the supply of plant proteins for human and animal consumption. India has been well known for the production of a wide range of oilseed cakes from its native oil seeds and other plant sources. Oilseed cakes are the residues obtained after the extraction of oil from the plant source such as oilseed, by expelling or solvent extraction. Extraction of oil from seed or fruit is carried out by two methods: by pressing, or with chemical solvents. The product obtained by pressing is termed oilcake and that by solvent extraction, oil meal. Oilcake production is carried out by one of two mechanical processes. Oil cakes are by-products obtained after oil extraction from the seeds. Oilseed cakes are of two types, edible and non-edible. Those cakes resulting from edible oil-bearing seeds which are being used to meet a part of the nutritional requirements of either animal-feed or of human consumption are called as edible oil cakes and those which cannot be used as feed stuff due to the presence of toxic compounds and other impurities are differentiated as non-edible (Mitra and Misra 1967). Oilseed cakes are rich in fiber and have high concentration of non-starch polysaccharides (NSP) (Bharathidasan et al. 2008). Their chemical composition varies due to the differences in the extraction methods of oil. Oilseed cakes such as palm kernel cake, sesame cake and copra cake contain 14–20 % of crude protein. However, groundnut cake contains 40–50 % of crude protein. These cakes are used for the production of value added fine products in the area of enzyme and fermentation technology (Pandey et al. 2000).

Rice bran is the brown outer layer of the brown rice kernel that is removed when milling brown rice to milled or white rice. Rice bran is an excellent source of proteins, oils, vitamins, fibers and antioxidants and used for human food supplements. Copra cake has a protein content of 20 % and also a good source of minerals especially electrolytes (sodium and

potassium) and fibers. Sesame cake is found to be an excellent source of antioxidant activity due to the presence of lignans (Suja et al. 2005). The occurrences of some antinutritional compounds have been reported. Among these are trypsin inhibitors, pepsin inhibitors, hemaglutinin, phytates and tannins. Fortunately, activity of these compounds is relatively low and can be inactivated by heat treatment (Khalil and Mansour 1995). High fiber diets are associated with the prevention and treatment of some diseases such as constipation, diverticular disease, colonic cancer, coronary heart disease and diabetes (Anderson et al. 1994; Cassidy et al. 1994). Oilseed cakes are rich in protein contents and can be utilized through development of new products and fortification of products such as conophor nut-based biscuits (Adebona et al. 1988) and shelf stable bread-spread from African oil bean seeds (Enujiugha 2000).

The aim of this study was to evaluate the potential of oil cakes and raw materials for the utilization for the food supplementation. These starting cakes and raw materials were processed and made edible by giving certain treatments such as cooking and evaluated for nutrient compositions such as protein, fibers and minerals. These starting cakes and raw materials also contain some percentage of oil after extraction, the fat further analyzed for fatty acid profile and nutraceutuical contents like oryzanol in rice bran and lignans in sesame oils. These were also analyzed for the sensory evaluation.

Materials and methods

Collection of samples

The rice bran pellets, stabilized rice bran, copra cake and sesame cake were collected from the industries, these were ground into powder using mixer cum grinder and processed in the lab with suitable treatments and to investigate their nutritional composition and compare the results with their raw materials. All chemicals and solvents used were of analytical grade.

Product preparation

Raw rice bran pellets, stabilized rice bran, copra cake and sesame cake were taken for the study. These were processed in the lab with suitable treatments and used for the incorporation for the supplementation of foods. These were mixed with distilled water and cooked in such a way to separate the cooked solid residue and liquid extract followed by freeze drying ('ScanVac' FREEZE DRIER model: Cool Safe 55-9 *Pro* with Drying Chamber, Denmark) at −55 °C to get two products from each.

Nutritional composition analysis of rice bran pellets, stabilized rice bran, copra cake and sesame cake

The raw rice bran pellets (RBP), stabilized rice bran (SRB), copra cake (CC), sesame cake (SK) and their respective cooked residues and extracts: rice bran pellets residue (RBPR), rice bran pellets extract (RBPE), stabilized rice bran residue (SRBR), stabilized rice bran extract (SRBE), copra cake residue (CCR), copra cake extract (CCE), sesame cake residue (SCR), sesame cake extract (SCE) were analyzed for various parameters such as moisture, fat, protein, crude fiber, dietary fiber (soluble and insoluble), ash and mineral contents. Carbohydrate content was calculated by the difference. The percentage of cooked residue and extract products were ranged from 60–83 % and 17–40 % from raw materials.

Moisture content The samples were ground to a fine powder; 10 g of the ground samples were taken in aluminum moisture cups and placed in an oven at 100±1 °C for 2 h or till a constant weight was obtained. The moisture contents were expressed on dry basis (method no. Ac 2–41 1997) (AOCS 1998).

Fat content Analysis was carried out by AOCS Official Butttube Method Ac 3–44 (AOCS 1998). The raw rice bran's, oil cakes and their cooked residues and extracts were ground to a fine powder, dried in oven at 100±1 °C, packed in 26 mm× 60 mm thimbles and extracted with hexane in Soxhlet apparatus. The extracts was desolventized by vacuum flash evaporation (Rotavapor RE 121A, Buchi, Switzerland) at controlled temperature and were subjected to various analyses.

Protein content (AOAC Official method 950.48) The micro-Kjeldahl method was used to determine total proteins (AOAC 1997). Briefly, 1 g of sample was placed in a micro-Kjeldahl flask. A catalyst (mixture of 0.42 g of $CuSO_4$+9.0 g of K_2SO_4), a few glass beads (to prevent sample bumping), and 15 ml of concentrated H_2SO_4 (36 N) were added to each sample. Sample digestion was done at 410 °C for 8–10 h (until a clear green solution was obtained, which ensured complete oxidation of all organic matter). The digest was diluted with 50 ml of distilled water, and the micro-Kjeldahl flask was attached to the distillation unit. After the addition of 45 ml of 15 N NaOH, sample distillation was commenced and released ammonia was collected into a boric acid solution containing the indicators methylene blue and methyl red. Borate anion (proportional to the amount of nitrogen) was titrated with standardized 0.1 N H_2SO_4. A reagent blank was run simultaneously. Sample nitrogen content was calculated using the formula.

Dietary fiber content The estimation of dietary fiber in the samples was done according to the enzymatic gravimetric

method described by Asp et al. (Asp et al. 1983) Briefly, deffated sample (1 g) was suspended in 25 ml of 0.1 M phosphate buffer (pH 6), then 0.1 ml of Thermo amylase was added and the mixture was kept in a boiling water bath for 15 min to digest starches. The contents were cooled, 20 ml of water was added and the pH was adjusted to 1.5 with 4 N HCl. Proteins were digested with 100 mg of pepsin at 40 °C for 1 h. Then 20 ml of water was added and the pH was adjusted to 6.0 with 4 M NaOH. Subsequently, 100 mg of pancreatin was added and the mixture was incubated at 40 °C for 1 h. Finally, the contents were cooled, the pH was adjusted to 4.5 with 4 N HCl and the mixture was filtered through a dried and weighed crucible containing celite (0.5 g). To obtain insoluble dietary fiber, the residue retained in the crucible was washed with 95 % of 20 ml ethanol followed by acetone. The crucible was kept in an oven (105 °C) until the weight became constant and its final weight was determined. The sample-containing crucible was then incinerated at 550 °C for 5 h and its weight was determined. To obtain soluble dietary fiber, the volume of the filtrate was adjusted to 100 ml and the soluble fiber was precipitated by adding 4 volumes of warm (60 °C) ethanol. The precipitate was filtered through a crucible containing celite, dried at 105 °C and the weight of the crucible was determined. The sample-containing crucible was then incinerated at 550 °C for 5 h and its weight was determined. Blanks were prepared as above but without the sample.

Ash content A known weight of the sample was initially charred on a tared silica crucible and placed in a muffle furnace at 550 °C for 6 h till the charred material became white. The dish was allowed to cool to room temperature in a desiccator and reweighed. The difference in weight was taken as total ash content (AOAC 1997).

Mineral estimations Iron, zinc, sodium, potassium and calcium content of raw rice bran pellets, stabilized rice bran and starting cakes and their cooked residue and extracts were analyzed by atomic absorption spectroscopy (AAS) (Raghuramulu et al. 2003).

Analysis of extracted oil

The raw rice bran pellets, stabilized rice bran, starting cakes and their cooked residues and extract oils were analyzed for fatty acid compositions, oryzanol content in rice bran (rice bran pellets and stabilized rice bran) and lignans content in the sesame cake oil.

Fatty acid composition Fatty acid methyl esters (FAME) of the oil samples were prepared by transesterification, according to AOCS Method No: Ce 1–62, 1998 (AOCS 1998). FAMEs were analyzed on a Fisons 8000 series gas chromatograph (Fisons Co., Italy), equipped with a flame ionization detector (FID) and a fused silica capillary column (100 m×0.25 mm i.d.), coated with 0.20*l*m SP2560 (Supelco Inc., Bellefonte, PA) as the stationary phase. The oven temperature was programmed from 140 to 240 °C at 4 °C/min with an initial hold at 140 °C for 5 min. The injector and FID were at 260 °C. A reference standard FAME mix (Supelco Inc.) was analyzed under the same operating conditions to determine the peak identity. The FAMEs were expressed as relative area percentage.

Oryzanol content Oryzanol content was determined by spectrophotometric method using UV–vis spectrophotometer (model-UV-1601, Shimadzu, Kyoto, Japan) by measuring the optical density at 314 nm of the oil taken in hexane followed by calculation using the extinction coefficient of 358.9 and expressed as g/100 g of oil and reported as milligram/100 g of oil (Gopala Krishna et al. 2006).

Analysis of lignans Analysis of lignans in sesame cake and its coked residue and extract were performed by HPLC (model LC-10A VP Shimadzu corporation, Kyoto, Japan) equipped with a UV-detector (290 nm) on a C18 phenomenex column (250 mm length *3* 4.6 mm i.d.) using 70 % methanol as the mobile phase according to Kamal Eldin and Appelqvist (Kamal-Eldin and Appelqvist 1994). Standard sesamol and sesamin were used for the quantitation of lignans in the sample.

Sensory attributes Sensory evaluations of the starting cakes, raw materials and cooked (residues and extracts) products were carried out by 20 untrained taste panelists. They were instructed to taste the samples and to rinse their mouth after each sample taste. They were requested to express their feelings about the samples by scoring the following attributes: appearance, texture, taste, aroma and overall acceptability. Sensory scores were based on a nine point hedonic scale, where one is dislike extremely and nine are like extremely (Watts et al. 1989).

Statistical analysis The experiment was carried out in quadruplicate. All the quality parameters were analysed in quadruplicate and the data obtained for each parameters were expressed as mean ± standard deviation. One-way anova was used to calculate significant difference in the oils and residues (Steele and Torrie 1980).

Results and discussion

Table 1 depicts the data for the moisture, fat, ash, protein and crude fiber content of RBP, SRB, CC, SC and their residues of

Table 1 Proximate composition of rice bran, copra and sesame oilcakes and their water extracts and residual solids

Samples	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Crude fiber (%)	Carbohydrates (%)
RBP (100 %)	8.2±0.02^{a}	11.8±0.12^{a}	7.5±0.01^{a}	9.9±0.02^{a}	9.8±0.05^{a}	52.8
RBPR (66 %)	10.1±0.05^{b}	12.4±0.02^{a}	7.1±0.01^{b}	6.5±0.52^{b}	6.1±0.02^{b}	57.8
RBPE (34 %)	6.7±0.01^{c}	10.7±0.01^{b}	7.2±0.04^{b}	3.2±0.12^{c}	3.3±0.08^{c}	68.9
RBS (100 %)	0.9±0.1^{d}	16.1±0.25^{c}	7.6±0.02^{a}	10.4±0.4^{a}	10.5±0.01^{d}	54.5
RBSR (60 %)	21.6±0.32^{e}	10.3±0.08^{b}	6.4±0.08^{c}	5.9±0.1^{b}	5.8±0.06^{b}	50.0
RBSE (40 %)	12.8±0.44^{f}	15.8±0.32^{c}	7.3±0.24^{ab}	4.8±0.22^{d}	4.4±0.01^{e}	54.9
CC (100 %)	9.9±0.0^{ba}	9.4±0.01^{d}	4.9±0.06^{d}	17.8±0.1^{e}	10.3±0.08^{d}	47.7
CCR (74 %)	8.2±0.01^{a}	7.7±0.04^{e}	3.3±0.29^{e}	12.2±0.35^{f}	7.2±0.05^{f}	61.4
CCE (26 %)	27.4±0.06^{g}	0.0	7.3±0.24^{ab}	4.9±0.36^{d}	2.7±0.1^{g}	57.7
SC (100 %)	9.2±0.33^{ab}	9.3±0.14^{d}	8.9±0.16^{f}	34.0±0.22^{g}	8.2±0.08^{h}	30.4
SCR (83 %)	8.9±0.01^{ab}	10.4±0.08^{b}	9.0±0.44^{f}	25.4±0.42^{h}	6.1±0.2^{b}	40.2
SCE (17 %)	26.2±0.12^{h}	2.1±0.04^{f}	8.7±0.05^{f}	6.9±0.02^{b}	1.9±0.06^{i}	54.2

Values reported are mean ± SD (n=6). Values in columns followed by different superscripts are significantly different (p<0.05)

RBP Rice bran pellets, *RBPR* Rice bran pellets residue, *RBPE* Rice bran pellets extract, *RBS* Rice bran stabilized, *RBSR* Rice bran stabilized residue, *RBSE* Rice bran stabilized extract, *CC* Copra cake, *CCR* Copra cake residue, *CCE* Copra cake extract, *SC* Sesame cake, *SCR* Sesame cake residue, *SCE* Sesame cake extract

RBPR, SRBR, CCR, SCR and extracts of RBPE, SRBE, CCE, SCE. Carbohydrate content was calculated by difference. The cooked products (solid residue and liquid extract) showed significant differences (P<0.05) of nutrients in the fat, ash, protein and crude fiber from the starting cakes and raw materials. These differences were due to the cooking treatment to the starting cakes and raw materials. The changes were observed due to leaching of soluble components in to the extract (Saikai et al. 1999). The moisture content was ranged from 0.94 to 27.40 %. SRB as such showed lowest moisture content (0.9 %) compared to others but its residue SRBR and extract SRBE showed 21.6 and 12.80 % after cooking in water. The highest moisture contents were found to be in extracts of cakes (CCE and SCE) and lowest in residues of RBPR, CCR and SCR and except SRBR (21.6 %). Estimation of lipids is considered amongst the key factors for nutritional evaluation of any material (Ayaz et al. 2006). The oil content of rice bran pellets and stabilized rice bran were 11.8 % and 16.1 % and agreed well with those reported for rice bran (ICAR 1964 and Bhattacharya 1988). The values compared well with those reported for oil seed cakes. The oil content of starting cakes, raw materials and cooked products were in the range of 2.14–16.08 %, the oil content of SRB as such was found to be highest (16.08 %) whereas the lowest (2.14 %) was found for SCE. There was no oil content found in the CCE and there was no much significant difference in the oil content of starting cakes, raw materials and cooked products except in CCE and SCE. Fat content of the oil cakes is also dependent on the oil extraction method (Swick 1999). The lipid content in sesame cake was lower than that reported by Suja et al. (2004). Ash contents varied between 3.33 and 9.0 %. There was a change in ash content of CC and its residue (CCR) and extract (CCE) (3.33–7.3 %). CCR showed lowest ash content (3.33 %) compared to all.

The protein content of products decreased significantly (p<0.05) on cooking. Protein digestibility was found to decrease with formation of isopeptides and highly polymer protein fractions during heat treatments (Yagoub et al. 2004). The protein content was in the range of 3.18–33.87 %. SC is a by-product of sesame oil industry, an excellent source of protein and used as a value added products for the incorporation of food products (Escamilla-Silva et al. 2003). The protein content of SC was more (33.87 %) comparable to CC, RBP and SRB. CC had a protein content of 17.83 % and RBP and SRB were in the range of 3.18–10.42 %. The crude fiber was in the range of 1.9–10.5 %.

Raw RBP, SRB, CC, SC and their cooked residues (RBPR, SRBR, CCR and SCR) and cooked filtrates (RBPE, SRBE, CCE and SCE) were analyzed for the total dietary fiber (soluble and insoluble) and are presented in the Table 2. The total dietary fiber of rice bran pellets and stabilized were ranged from 28.7 to 29.8 % and these values were agreed well with those reported for the total dietary fiber in defatted rice bran (Abdul-Hamid and Luan 2000). The insoluble dietary fiber content was higher in all these compared to soluble dietary fiber. The soluble and insoluble dietary fiber ranged from 1.9 to 6.1 % and 19.5 to 56.10 % respectively. The lowest total dietary fiber content was in RBSR (23.2 %) and highest in CC as such (58.2 %). There was no much significant difference observed in the starting cakes, raw materials and their cooked residues and filtrates although insoluble dietary fiber decreased and soluble dietary fiber has been increased in the RBPR and SRBR when compared to its residue and as such.

Table 2 Dietary fiber content of rice bran, copra and sesame oilcakes and their water extracts and residual solids

Samples	Dietary fiber (%)		Total dietary fiber (%)
	Soluble	Insoluble	
RBP (100 %)	6.1±0.01[a]	23.7±0.06[a]	29.8±0.01[a]
RBPR (66 %)	4.0±0.05[b]	19.5±0.08[b]	23.5±0.05[b]
RBPE (34 %)	5.1±0.1[c]	27.1±0.04[c]	32.2±0.04[c]
RBS (100 %)	3.1±0.06[d]	25.6±0.02[d]	28.7±0.08[d]
RBSR (60 %)	2.4±0.22[e]	20.8±0.08[e]	23.2±0.10[e]
RBSE (40 %)	4.4±0.18[f]	28.2±0.01[f]	32.6±0.12[f]
CC (100 %)	2.7±0.05[eg]	55.6±0.01[g]	58.3±0.08[g]
CCR (74 %)	1.8±0.01[h]	56.1±0.16[h]	57.9±0.04[h]
CCE (26 %)	2.8±0.06[dgi]	27.4±0.14[c]	30.2±0.06[i]
SC (100 %)	2.4±0.22[eg]	50.5±0.15[i]	52.9±0.04[j]
SCR (83 %)	4.1±0.15[bf]	45.7±0.32[j]	49.8±0.02[k]
SCE (17 %)	2.7±0.28[egi]	48.2±0.21[k]	50.9±0.01[l]

Values are average of triplicate determinations. Values with different superscript in the columns showed significant difference at $P<0.001$

RBP Rice bran pellets, *RBPR* Rice bran pellets residue, *RBPE* Rice bran pellets extract, *RBS* Rice bran stabilized, *RBSR* Rice bran stabilized residue, *RBSE* Rice bran stabilized extract, *CC* Copra cake, *CCR* Copra cake residue, *CCE* Copra cake extract, *SC* Sesame cake, *SCR* Sesame cake residue, *SCE* Sesame cake extract

Table 4 Nutraceutical contents of oils from rice bran, copra and sesame oilcakes and their water extracts and residual solids

Samples	Oryzanol (mg/100 g)	Lignans (mg/100 g)
RBP (100 %)	194±0.12[a]	–
RBPR (66 %)	214±0.02[b]	–
RBPE (34 %)	172±0.22[c]	–
RBS (100 %)	258±0.10[d]	–
RBSR (60 %)	138±0.15[e]	–
RBSE (40 %)	239±0.22[f]	–
SC (100 %)	–	99±0.01[a]
SCR (83 %)	–	113±0.05[b]
SCE (17 %)	–	–

Values are average of triplicate determinations. Values with different superscript in the columns showed significant difference at $P<0.001$

RBP Rice bran pellets, *RBPR* Rice bran pellets residue, *RBPE* Rice bran pellets extract, *RBS* Rice bran stabilized, *RBSR* Rice bran stabilized residue, *RBSE* Rice bran stabilized extract, *CC* Copra cake, *CCR* Copra cake residue, *CCE* Copra cake extract, *SC* Sesame cake, *SCR* Sesame cake residue, *SCE* Sesame cake extract

There was a wide variation in the minerals content on these and analyzed five mineral elements as indicated in Table 3. The values compared well with those reported for oil seed cakes. Off all the nutritionally valuable minerals analyzed, calcium (Ca), potassium (K) and sodium (Na) were most abundant while Zn was the least abundant. The differences in the starting cakes, raw materials and cooked products were due to the effect of processing in cooked products. Iron contents ranged from 7.33 to 59.52 mg/100 g and the highest level of iron was found in the SCR (59.52 mg/100 g) and lowest in SRBE. The zinc content was less compared to other minerals in these samples (2.57–13.0 mg/100 g). Sodium content was determined to be highest only in the CC, CCR and CCE (27.29–52.91 mg/100 g) among all. Potassium content was in the range of 42.71–117 mg/100 g, highest was observed in CC and SC. The highest level of mineral found was calcium among all minerals

Table 3 Mineral compositions of the rice bran, copra and sesame oilcakes and their water extracts and residual solids

Samples	Minerals content (mg/100 g)				
	Iron	Zinc	Sodium	Potassium	Calcium
RBP (100 %)	14.2±0.02[a]	4.5±0.08[a]	20.2±0.12[a]	89.5±0.14[a]	54.8±0.01[a]
RBPR (66 %)	13.3±0.11[b]	4.4±0.18[ab]	24.0±0.24[b]	115.5±0.32[b]	74.4±0.22[b]
RBPE (34 %)	13.5±0.42[b]	4.9±0.1[a]	11.5±0.14[c]	46.0±0.26[c]	9.7±0.33[c]
RBS (100 %)	15.3±0.10[c]	4.8±0.28[a]	11.1±0.34[c]	75.7±0.24[d]	49.1±0.23[d]
RBSR (60 %)	18.9±0.52[d]	3.8±0.33[c]	16.6±0.24[d]	99.4±0.38[e]	75.1±0.44[e]
RBSE (40 %)	7.3±0.18[e]	3.8±0.24[c]	7.9±0.10[e]	42.7±0.08[f]	7.5±0.01[f]
CC (100 %)	21.4±0.15[f]	5.4±0.11[g]	33.6±0.20[f]	112.6±0.18[g]	70.3±0.18[g]
CCR (74 %)	24.8±0.44[g]	6.5±0.22[h]	27.3±0.33[g]	114.4±0.29[h]	72.8±0.22[h]
CCE (26 %)	7.3±0.22[e]	2.6±0.14[i]	52.9±0.11[h]	98.1±0.01[i]	58.9±0.02[i]
SC (100 %)	55.6±0.01[h]	13.0±0.05[j]	23.3±0.22[i]	117.0±0.04[j]	560.9±0.06[j]
SCR (83 %)	59.5±0.08[i]	9.9±0.02[k]	23.9±0.32[b]	111.0±0.06[k]	633.2±0.05[k]
SCE (17 %)	11.3±0.22[j]	4.0±0.05[bc]	16.9±0.25[l]	97.4±0.08[l]	144.4±0.01[l]

Values reported are mean ± SD ($n=6$). Values with different superscript in the columns showed significant difference at $P<0.001$

RBP Rice bran pellets, *RBPR* Rice bran pellets residue, *RBPE* Rice bran pellets extract, *RBS* Rice bran stabilized, *RBSR* Rice bran stabilized residue, *RBSE* Rice bran stabilized extract, *CC* Copra cake, *CCR* Copra cake residue, *CCE* Copra cake extract, *SC* Sesame cake, *SCR* Sesame cake residue, *SCE* Sesame cake extract

Table 5 Fatty acid composition of the oil extracted from different raw materials before and after processing

Samples	$C_{6:0}$	$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:0}$	SFA	MUFA	PUFA
RBP (100 %)	nd	nd	nd	0.7	0.5	21.4	0.9	44.7	31.8	nd	nd	23.5	44.7	31.8
RBPR (66 %)	nd	nd	nd	0.4	0.4	19.9	0.4	46.4	31.4	nd	1.1	22.2	46.4	31.4
RBPE (34 %)	nd	nd	nd	0.7	0.4	21.0	0.4	46.8	30.3	nd	nd	23.0	46.8	30.3
RBS (100 %)	nd	nd	nd	0.5	0.5	22.8	0.5	43.6	30.7	nd	1.4	25.7	43.6	30.7
RBSR (60 %)	nd	nd	nd	0.3	0.5	26.1	0.1	40.8	31.1	nd	1.4	28.1	41.3	30.4
RBSE (40 %)	nd	nd	nd	0.1	0.4	26.1	0.1	40.8	31.1	nd	1.4	28.1	40.8	31.1
CC (100 %)	0.4	8.8	6.3	44.0	21.9	9.9	1.4	5.4	1.7	nd	nd	92.7	5.4	1.7
CCR (74 %)	nd	nd	1.1	26.8	11.1	49.9	9.6	1.5	nd	nd	nd	98.5	1.5	0.0
CCE (26 %)	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
SC (100 %)	nd	nd	0.1	0.4	0.2	11.4	1.3	44.3	42.3	nd	nd	13.4	44.3	42.3
SCR (83 %)	0.3	0.4	3.7	1.5	12.3	0.2	1.5	45.7	34.4	nd	nd	19.9	45.7	34.4
SCE (17 %)	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Values are average of triplicate determinations

RBP Rice bran pellets, *RBPR* Rice bran pellets residue, *RBPE* Rice bran pellets extract, *RBS* Rice bran stabilized, *RBSR* Rice bran stabilized residue, *RBSE* Rice bran stabilized extract, *CC* Copra cake, *CCR* Copra cake residue, *CCE* Copra cake extract, *SC* Sesame cake, *SCR* Sesame cake residue, *SCE* Sesame cake extract, *nd* not detected

determined in these samples. The calcium level was ranged from 7.52 to 633.1 mg/100 g and it was more in SCR (633.1 mg/100 g) and SC (560.9 mg/100 g). SC was found to be a good source of calcium, potassium and iron content among others. CC was rich in potassium and sodium. As observed, cooking resulted in significantly increased in trace elements of cooked residue than raw materials and cooked extract which could be attributed to effect of cooking on changing the soluble chemical species of some trace elements in to insoluble ones thus extracted more in the cooked residue. Abu El Gasim et al. (2008) reported that Cooking was more effective in improving the bio availability of minerals.

The RBP, SRB and SC were having 10.65–12.44 %, 10.26–16.08 % and 2.14–10.39 % of oil content in the cake as provided in the Table 4. From the data, it is clear that, after oil extraction the RBP, SRB and SC still retain the oryzanol and lignans. Suja et al. (2005) have also reported lignans from sesame cake after oil extraction. Hence, RBP, SRB and SC, form a cheaper source for the food supplementation. These oils were analyzed for nutraceuticals like oryzanol and lignans content by percentage of cake basis. The oryzanol content in RBP ranged from 172 to 214 mg/100 g and SRB ranged from 138 to 239 mg/100 g. The SRB was found to be having more oryzanol content with RBP. This was due to the stabilization

Table 6 Mean sensory scores of cooked and uncooked rice bran, copra and sesame oilcakes and their water extracts and residual solids

Sensory attribute	Appearance	Texture	Taste	Aroma	Overall acceptability
RBP (100 %)	4.0 ± 0.01^{a}	3.2 ± 0.08^{a}	3.2 ± 0.01^{a}	5.1 ± 0.01^{a}	3.8 ± 0.22^{a}
RBPR (66 %)	7.8 ± 0.05^{b}	7.5 ± 0.02^{b}	6.6 ± 0.01^{b}	7.2 ± 0.06^{b}	7.3 ± 0.32^{b}
RBPE (34 %)	6.2 ± 0.02^{c}	7.5 ± 0.02^{b}	4.5 ± 0.04^{c}	5.1 ± 0.05^{a}	5.8 ± 0.01^{c}
RBS (100 %)	5.5 ± 0.10^{d}	4.1 ± 0.1^{c}	3.4 ± 0.04^{a}	3.6 ± 0.16^{c}	4.1 ± 0.01^{a}
RBSR (60 %)	7.9 ± 0.22^{b}	8.2 ± 0.15^{d}	7.6 ± 0.12^{d}	6.2 ± 0.15^{d}	7.5 ± 0.05^{b}
RBSE (40 %)	7.5 ± 0.02^{e}	7.1 ± 0.05^{e}	5.1 ± 0.33^{e}	5.5 ± 0.22^{e}	6.2 ± 0.01^{d}
CC (100 %)	3.3 ± 0.06^{f}	2.2 ± 0.08^{f}	3.6 ± 0.22^{f}	5.0 ± 0.02^{f}	3.5 ± 0.02^{e}
CCR (74 %)	5.6 ± 0.04^{g}	5.9 ± 0.06^{g}	7.9 ± 0.01^{g}	6.2 ± 0.01^{g}	6.4 ± 0.02^{f}
CCE (26 %)	5.5 ± 0.1^{h}	5.2 ± 0.05^{h}	5.2 ± 0.05^{h}	5.6 ± 0.04^{h}	5.4 ± 0.25^{g}
SC (100 %)	2.2 ± 0.22^{i}	2.6 ± 0.25^{i}	3.9 ± 0.02^{i}	5.5 ± 0.06^{i}	3.5 ± 0.22^{h}
SCR (83 %)	6.9 ± 0.24^{j}	5.5 ± 0.01^{j}	7.7 ± 0.05^{j}	6.6 ± 0.05^{j}	6.8 ± 0.36^{i}
SCE (17 %)	6.6 ± 0.08^{k}	5.2 ± 0.01^{k}	5.8 ± 0.01^{k}	5.4 ± 0.08^{k}	5.8 ± 0.42^{j}

Values reported are mean ± SD (n=6). Values with different superscript in the columns showed significant difference at $P<0.001$

RBP Rice bran pellets, *RBPR* Rice bran pellets residue, *RBPE* Rice bran pellets extract, *RBS* Rice bran stabilized, *RBSR* Rice bran stabilized residue, *RBSE* Rice bran stabilized extract, *CC* Copra cake, *CCR* Copra cake residue, *CCE* Copra cake extract, *SC* Sesame cake, *SCR* Sesame cake residue, *SCE* Sesame cake extract

of rice bran retained more oryzanol content in it. Sesame oil is rich in antioxidant like lignans even after extraction of oil from sesame cake; the cake was having 9.25–10.39 % of oil content. Lignans content ranged from 99 to 113 mg/100 g of SC.

The fatty acid composition of fat of RBP, SRB, CC and SC shows in the Table 5. There was no significant difference in the fatty acid composition of starting cakes, raw materials and cooked products. RBP and SRB were having well balanced fatty acid composition and their S: M: P ratio was almost near to 1:1:1. CC was rich in SFA (92.7–98.5 %) and poor source of MUFA and PUFA and SC was rich in oleic and linoleic acids.

The sensory evaluation of starting cakes, raw materials and cooked products shows in the Table 6. The results showed that cooked residues and extracts were more acceptable by the panelists compared to cooked extract, starting cakes and raw materials. This indicates that these processed products could be used as sources of nutrients such as protein, fat, carbohydrate, minerals, dietary fiber and nutraceuticals such as oryzanol and lignans. Because of their palatability and richness in nutrients, these cooked products can be used for food supplementation for human consumption.

Conclusion

From the results of present study, the following conclusions can be drawn from starting cakes, raw materials and cooked RBP, SRB, CC, SC for their food supplementation. There were significant difference in the nutritional composition and sensory attributes of starting cakes, raw materials and their cooked solid residue and cooked liquid extract and were affected by processing methods. The cooked residue products retained more nutrients than cooked extracts and they are rich sources of protein, fat and dietary fibers, a good source of minerals like calcium, potassium, sodium, iron & zinc and also antioxidants like oryzanol in rice bran and lignans in sesame cake. The cooked products were well gelatinized, palatable, appealing good and acceptable by the sensory panelists compared to starting cakes and raw materials. Hence, these cooked products are highly valuable for food supplementation.

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