Development of baked and extruded functional foods from metabolic syndrome specific ingredient mix

Neetu Miglani · Kiran Bains · Harpreet Kaur

Revised: 7 October 2014 / Accepted: 3 November 2014 / Published online: 25 November 2014
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Abstract The study was aimed to develop baked and extruded functional foods from Metabolic Syndrome (MS) specific designed ingredient mixes with optimum amino acid makeup using key food ingredients with functional properties such as whole cereals, legumes, skimmed milk powder, along with flaxseeds and fenugreek seeds. Two cereals viz. barley and oats and four pulses viz. mung bean, cowpea, bengal gram and soybean were blended in different proportions in order to balance the limiting amino acid lysine in the wheat flour. Three products namely bread, extruded snack and noodles prepared from twenty five ingredient mixes. Six ingredient mixes of breads and four ingredient mixes each of extruded snack and noodles specifically designed for MS patients were organoleptically at par with control wheat flour products. The acceptable products had significantly ($p \leq 0.05$) higher lysine, crude protein, ash and fibre and low carbohydrates in compare control whole wheat flour products, hence appropriate for MS patients.

Keywords Metabolic syndrome · Lysine · Functional food · Bread · Extruded snack · Noodles

Introduction

Metabolic syndrome (MS) is a complex web of metabolic factors that are associated with a 2-fold risk of cardiovascular disease (CVD) and a 5-fold risk of diabetes. Individuals with MS have a 30–40 % probability of developing diabetes and/or CVD within 20 years, depending on the number of

components present (Enas et al. 2007). Basically, the risk factors for metabolic syndrome are insulin resistance and abdominal obesity (Park et al. 2003). Recently, it has been noticed that an Asian Indian phenotype has high body fat with relatively less body mass index, less lean body mass and marked abdominal obesity owing to the amino acid imbalance. In this context, new evidence reveals an increasingly complex role for protein and amino acids in regulation of body composition, glucose homeostasis, cell signalling, and satiety (Donald et al. 2008; Millward et al. 2008). Well nourished Indians showed a trend toward improved muscle function with higher lysine intakes. There are several lines of reasoning to suggest that lysine intake may influence muscle function (Kurpad et al. 2002).

Cereal-based diet is typical in India and the traditional vegetarian Indian meals usually include foods from different sources in order to improve their protein quality (Vaidya and Sheth 2011). The concern for optimum protein quality to prevent metabolic abnormalities holds significance for a large lacto vegetarian population of India which depends on plant foods for obtaining essential amino acids (Singh 2008). Optimum protein quality from meals along with physically active lifestyle may help the people to have right proportion of fat mass and lean mass which may have protective role against MS. With the growing epidemic of obesity and the MS, reduction in the consumption of refined carbohydrates and sugar, replaced by either minimally processed whole grain products and healthy sources of fats and protein, should become a major public health priority, together with regular physical activity and weight maintenance. The aim of the study was to formulate the MS specific ingredient mix with optimum amino acid make up using key food ingredients with reported functional properties. The nutritionally superior and organoleptically acceptable baked and extruded products developed from such ingredient mixes may help to reverse the features of MS.

N. Miglani · K. Bains (✉) · H. Kaur
Department of Food and Nutrition, Punjab Agricultural University,
Ludhiana 141004, Punjab, India
e-mail: kiranbains68@hotmail.com

Materials and methods

Procurement of food ingredients

For preparation of ingredient mixes, three cereals viz. whole wheat, barley and oats; four pulses viz. Mung bean, cowpea, bengal gram and soybean; skimmed milk powder, fenugreek seeds and flax seeds were procured in one lot from the local market and stored in air tight containers.

Designing of ingredient mixes

In order to balance the limiting amino acid lysine in the wheat flour, 25 ingredient mixes were designed by correcting the chemical score as recommended by FAO/WHO/UNU (1985) using food composition tables of ICMR (2010). These ingredient mixes were designed using foods with reported functional properties such as whole cereals and pulses were chosen for their soluble fiber and protein content, flaxseeds are rich source of omega-3 fatty acids and fenugreek seeds contain trigonelline alkaloids that help reducing blood glucose levels. The ingredients were used in proportions so as to reach the chemical score of 100. The lysine content of the foods was used to calculate the chemical score. The formulations of each ingredient mix used to prepare an individual product are shown in Table 1.

Development of functional foods

Functional foods namely Bread (Baked), Extruded snack and Noodles (Extruded products) were developed from whole wheat flour and all the twenty five designed ingredient mixes using cereals, legumes, skimmed milk powder, fenugreek seeds and flax seeds. Bread was prepared using straight dough AACC method numbered 10–11 (AACC 1984). Extruded snack were prepared using a co-rotating intermeshing twin screw extruder (Cletral, Firminy, France). Extrudates were dried and then packed in polythene bags. Noodle maker was used to extrude noodles from the dough by applying requisite amount of pressure and then oven dried at 50 °C for 3 h (Inglett et al. 2005). Three replications for product preparation were conducted.

Sensory evaluation of developed functional foods

The developed products were evaluated organoleptically thrice by a panel of ten semi trained panellists from the department of Food and Nutrition, Punjab Agricultural University, Ludhiana. The panellists were asked to score the samples on the basis of their color, appearance, texture, taste and overall acceptability by using a score card of 9 point Hedonic Rating Scale where 9 indicated “like extremely”

Table 1 Formulations of Metabolic Syndrome (MS) specific Ingredient mixes

Ingredient mixes	Flour composition	Amount of key ingredients (per 100 g)
Control	WW	100
1	WW+Mb+Fl+Fn	63+27+5+5
2	WW+Bar+Mb+Fl+Fn	49+16+25+5+5
3	WW+Bar+M+Fl+Fn	33+33+24+5+5
4	WW+Ot+Mb+Fl+Fn	49+16+25+5+5
5	WW+Ot+Mb+Fl+Fn	33+33+24+5+5
6	WW+Cp+Fl+Fn	62+28+5+5
7	WW+Bar+Cp+Fl+Fn	48+16+26+5+5
8	WW+Bar+Cp+Fl+Fn	33+33+24+5+5
9	WW+Ot+Cp+Fl+Fn	48+16+26+5+5
10	WW+Ot+Cp+Fl+Fn	33+33+24+5+5
11	WW+Bg+Fl+Fn	66+24+5+5
12	WW+Bar+Bg+Fl+Fn	50+17+23+5+5
13	WW+Bar+Bg+Fl+Fn	34+34+22+5+5
14	WW+Ot+Bg+Fl+Fn	50+17+23+5+5
15	WW+Ot+Bg+Fl+Fn	34+34+22+5+5
16	WW+Sb+Fl+Fn	60+30+5+5
17	WW+Bar+Sb+Fl+Fn	47+16+27+5+5
18	WW+Bar+Sb+Fl+Fn	32+32+26+5+5
19	WW+Ot+Sb+Fl+Fn	47+16+27+5+5
20	WW+Ot+S+Fl+Fn	32+32+26+5+5
21	WW+SM+Fl+Fn	65+25+5+5
22	WW+Bar+SM+Fl+Fn	50+16+24+5+5
23	WW+Bar+SM+Fl+Fn	34+34+22+5+5
24	WW+Ot+SM+Fl+Fn	50+16+24+5+5
25	WW+Ot+SM+Fl+Fn	34+34+22+5+5

Where, WW: whole wheat flour; Bar: barley flour; Ot: oat flour; Fl: flaxseeds; Fn: fenugreek seeds; Mb: mung bean; Cp: cowpea; Bg: Bengal gram; Sb: soybean and SM: skimmed milk powder

and 1 indicated “dislike extremely”. Each panelist was provided with enough privacy to avoid biased assessment.

The highly acceptable products along with their corresponding control were weighed, homogenized and oven dried at 60 °C. Dried samples were stored in air tight plastic bags for nutritional analysis.

Nutritional analysis

All the samples were analyzed in triplicates. Moisture, ash, protein, crude fat and crude fibre content was evaluated on dry matter basis by AOAC (2000) method Carbohydrates were calculated by difference. In vitro protein digestibility was estimated by the method of Akeson and Stachman (1964) modified by Singh et al. (1989). Available lysine was determined by FDNB method of Carpenter (1960) modified by Booth (1971).

Statistical analysis

Non parametric tests such as Tukey's and Dunken tests were used for selecting the best formulations through sensory evaluation. Means and standard deviations for various parameters of proximate analysis were computed using MS Excel. The data were subjected to ANOVA using the statistical analysis software (SAS) with a probability of $P \leq 0.05$.

Results and discussion

Sensory evaluation

Tables 2, 3 and 4 represent the organoleptic evaluation of baked and extruded products made up of 25 composite ingredient mixes whose formulations have been discussed earlier.

Out of 25 samples, breads made of ingredient mix 2, 6, 7, 8, 11 and 16 was at par with the control (whole wheat flour bread), having overall acceptability scores between 7.8 to 8.0. Breads made from ingredient mix 2, 7, 8, 9 and 16 were most acceptable having score range of 7.8 to 8.4. Similarly, for colour and texture, ingredient mix 2, 7, 8, 11 and ingredient mix 7, 8 and 11 were found to be most acceptable. Ingredient mix 2, 6 and 7 were having comparable taste with the control. These findings are thus supportive of those reported in the literature on the use of different flours as partial substitution of wheat flour in bread making. Addition of soy flour or other cereal pulse blends improve the nutritional quality of bread (Wang et al. 2002; Pacheco-Delahaye and Testa 2005). Addition of fenugreek seeds upto 20 % increases the functional properties of the breads as reported by Gamalth and Ganesharanee (2009). Hence, fenugreek seeds can be safely added to food systems such as bakery, not only as a nutrient but also as a functional agent.

Table 2 Sensory evaluation of developed breads

Ingredient mixes	Flour Composition	Appearance	Colour	Texture	Taste	Overall acceptability
Control	WW	8.90±0.07	8.70±0.08	8.90±0.10	8.80±0.06	8.80 ^a
1	WW+Mb+Fl+Fn	6.50±0.71	6.60±0.52	6.50±0.85	6.10±0.74	6.425 ^{def}
2	WW+Bar+Mb+Fl+Fn	7.80±0.63	7.90±0.32	7.90±0.32	8.20±0.63	7.950 ^b
3	WW+Bar+Mb+Fl+Fn	6.20±0.42	6.70±0.48	6.60±0.52	6.60±0.52	6.525 ^{de}
4	WW+Ot+Mb+Fl+Fn	6.60±0.70	6.20±1.03	6.70±0.67	6.10±0.74	6.400 ^{def}
5	WW+Ot+Mb+Fl+Fn	6.70±0.48	6.40±1.07	5.50±1.43	5.10±1.20	5.925 ^g
6	WW+Cp+Fl+Fn	7.70±0.48	7.60±0.52	7.80±0.42	8.00±0.03	7.775 ^b
7	WW+Bar+Cp+Fl+Fn	8.40±0.52	7.90±0.32	8.00±0.47	8.50±0.53	8.200 ^b
8	WW+Bar+Cp+Fl+Fn	7.90±0.32	7.80±0.42	8.00±0.47	7.80±0.42	7.875 ^b
9	WW+Ot+Cp+Fl+Fn	7.80±0.42	7.70±0.48	6.70±1.16	6.80±1.14	7.250 ^c
10	WW+Ot+Cp+Fl+Fn	6.50±1.18	6.20±0.92	5.90±1.29	5.70±1.06	6.075 ^{fg}
11	WW+Bg+Fl+Fn	7.60±0.70	8.00±0.94	8.00±0.67	7.80±0.63	7.850 ^b
12	WW+Bar+Bg+Fl+Fn	6.40±1.17	7.10±0.88	6.70±0.67	4.50±0.53	6.175 ^{defg}
13	WW+Bar+Bg+Fl+Fn	6.40±0.52	6.90±0.74	6.10±0.74	5.9±0.99	6.325 ^{defg}
14	WW+Ot+Bg+Fl+Fn	6.50±0.53	6.60±0.84	5.90±0.57	5.80±1.14	6.200 ^{defg}
15	WW+Ot+Bg+Fl+Fn	6.50±0.71	6.80±0.79	5.50±0.71	5.57±0.82	6.125 ^{efg}
16	WW+Sb+Fl+Fn	8.00±0.67	7.90±0.57	7.90±0.32	7.70±0.48	7.875 ^b
17	WW+Bar+Sb+Fl+Fn	6.70±1.16	6.70±0.95	6.60±0.70	6.40±0.70	6.600 ^d
18	WW+Bar+Sb+Fl+Fn	6.50±1.18	6.40±1.58	6.40±1.65	6.80±1.14	6.525 ^{de}
19	WW+Ot+Sb+Fl+Fn	6.50±1.08	6.80±1.03	5.90±1.37	5.80±1.14	6.250 ^{defg}
20	WW+Ot+Sb+Fl+Fn	6.90±0.88	6.10±1.21	5.90±1.10	5.50±1.08	6.100 ^{efg}
21	WW+SM+Fl+Fn	6.70±1.06	6.00±0.82	6.00±1.05	5.60±0.97	6.075 ^{fg}
22	WW+Bar+SM+Fl+Fn	6.50±0.53	6.30±0.82	6.50±0.95	5.50±0.53	6.150 ^{efg}
23	WW+Bar+SM+Fl+Fn	6.90±1.10	6.40±0.70	6.00±0.67	5.10±0.99	6.100 ^{efg}
24	WW+Ot+SM+Fl+Fn	6.80±0.92	6.50±0.53	5.90±0.74	5.20±1.03	6.100 ^{efg}
25	WW+Ot+SM+Fl+Fn	7.40±0.52	6.30±0.95	5.70±1.25	5.10±0.99	6.125 ^{efg}

Whole wheat: WW; Barley: Bar; Oats: Ot; Mungbean: Mb; Cowpea: Cp; Bengal gram: Bg; Soybean: Sb; Skimmed milk powder: SM; Flaxseeds: Fl; Fenugreek seeds: Fn) CD at 5 % = 0.436

Values are Mean±SD ^{a-g} Means within each row with different superscripts are significantly ($P < 0.05$) different

Table 3 Sensory evaluation of developed extruded snacks

Ingredient mixes	Flour Composition	Appearance	Colour	Texture	Taste	Overall acceptability
Control	WW	8.40±0.07	8.50±0.08	8.40±0.10	8.50±0.06	8.45 ^a
1	WW+Mb+Fl+Fn	6.50±0.71	6.60±0.52	6.10±0.85	6.42±0.74	6.425 ^{cdefg}
2	WW+Bar+Mb+Fl+Fn	7.80±0.63	7.90±0.32	7.90±0.32	8.20±0.63	7.950 ^b
3	WW+Bar+Mb+Fl+Fn	6.20±0.42	6.70±0.48	6.60±0.52	6.60±0.18	6.525 ^{cdef}
4	WW+Ot+Mb+Fl+Fn	6.60±0.70	6.20±1.03	6.70±0.67	6.10±0.74	6.400 ^{cdefg}
5	WW+Ot+Mb+Fl+Fn	6.70±0.48	6.40±1.07	5.50±1.43	5.10±1.20	5.925 ^h
6	WW+Cp+Fl+Fn	7.70±0.48	6.30±0.48	6.30±0.67	6.40±0.84	6.675 ^c
7	WW+Bar+Cp+Fl+Fn	6.70±1.16	6.70±0.95	6.50±0.53	5.40±0.52	6.325 ^{cdefgh}
8	WW+Bar+Cp+Fl+Fn	7.30±0.48	7.70±0.48	7.00±1.05	4.70±0.48	6.675 ^c
9	WW+Ot+Cp+Fl+Fn	7.00±0.12	6.60±1.07	6.70±1.16	5.90±0.57	6.550 ^{cde}
10	WW+Ot+Cp+Fl+Fn	6.50±1.18	6.20±0.92	5.90±1.29	5.70±1.06	6.075 ^{gh}
11	WW+Bg+Fl+Fn	8.30±0.48	8.30±0.67	8.60±0.52	8.20±0.42	8.350 ^b
12	WW+Bar+Bg+Fl+Fn	6.40±1.17	7.10±0.88	6.70±0.67	4.50±0.53	6.175 ^{defgh}
13	WW+Bar+Bg+Fl+Fn	8.00±0.11	8.20±0.42	8.90±0.32	8.00±0.11	8.275 ^b
14	WW+Ot+Bg+Fl+Fn	6.50±0.53	6.60±0.84	5.90±0.57	5.80±1.14	6.200 ^{defgh}
15	WW+Ot+Bg+Fl+Fn	6.50±0.71	6.80±0.79	5.50±0.71	5.70±0.82	6.125 ^{efgh}
16	WW+Sb+Fl+Fn	8.00±0.67	6.30±0.67	5.70±0.67	6.00±0.47	6.500 ^{cdefg}
17	WW+Bar+Sb+Fl+Fn	6.70±1.16	6.70±0.95	6.60±0.70	6.40±0.70	6.600 ^{cd}
18	WW+Bar+Sb+Fl+Fn	6.50±1.18	6.40±1.58	6.40±1.65	6.80±1.14	6.525 ^{cdef}
19	WW+Ot+Sb+Fl+Fn	6.50±1.08	6.80±1.03	5.90±1.37	5.80±1.14	6.250 ^{cdefgh}
20	WW+Ot+Sb+Fl+Fn	6.90±0.88	6.10±1.29	5.90±1.10	5.50±1.08	6.100 ^{fgh}
21	WW+SM+Fl+Fn	6.70±1.06	6.00±0.82	6.00±1.05	5.60±0.97	6.075 ^{gh}
22	WW+Bar+SM+Fl+Fn	8.00±0.11	7.70±0.67	8.5±0.53	8.30±0.48	8.125 ^b
23	WW+Bar+SM+Fl+Fn	6.90±1.10	6.40±0.70	6.00±0.67	5.10±0.99	6.100 ^{fgh}
24	W+Ot+SM+Fl+Fn	6.80±0.92	6.50±0.53	5.90±0.74	5.20±1.03	6.100 ^{fgh}
25	WW+Ot+SM+Fl+Fn	7.40±0.52	6.30±0.95	5.70±1.25	5.10±0.99	6.125 ^{efgh}

Whole wheat: WW; Barley: Bar; Oats: Ot; Mungbean: Mb; Cowpea: Cp; Bengal gram: Bg; Soybean: Sb; Skimmed milk powder: SM; Flaxseeds: Fl; Fenugreek seeds: Fn) Values are Mean SD CD at 5 % = 0.438^{a-h} Means within each row with different superscripts are significantly ($P < 0.05$) different

Ingredient mix 2, 11 and 13 were having best colour among the 25 samples of extruded snacks with mean scores of 7.9, 8.3 and 8.2, respectively. Ingredient mix 2, 11, 13 and 22 had the texture comparable to the control (mean value of 8.4). Taste wise, ingredient mix 2, 11, 13 and 22 were chosen from extruded snack. Noodles made of ingredient mix 11 turned out to be best in appearance, colour, taste and texture with mean scores of 8.2, 8.5, 8.5 and 8.2 respectively. The ingredient mix 2, 11, 13 and 22 for extruded snacks and ingredient mix 2, 7, 11 and 19 for noodles were statistically at par with their control counterparts. These ingredient mixes were found to have an overall acceptability score range between 7.95 to 8.35 for extruded snack and 7.95 to 8.35 for noodles. Addition of legume flour alters the textural properties of the extruded snacks and noodles. Shogren et al. (2006) confirmed that a high protein and lysine spaghetti can be made with 35 %

soy flour without adverse effect on the flavour and texture of the resulting products. As extruded snack products are predominantly made from cereal flour or starches and are generally low in protein and have low biological value (Iqbal et al. 2006), high level of protein combinations with protein rich sources can provide the basis for a range of highly nutritious extruded snack products (Ozer et al. 2004; Qing et al. 2005).

The proximate composition of bread, extruded snack and noodles is shown in Table 5. All the bread samples were having significantly ($p \leq 0.05$) high ash content as compared to their control counterparts. Whereas, ash content was found to be low in extruded snacks and significantly high in noodles as compared to control. The breads prepared from ingredient mixes 6, 7 and 8 had a significantly ($p \leq 0.05$) higher crude fibre content as compared to the control. Extruded snack made from ingredient mixes

Table 4 Sensory evaluation of developed noodles

Ingredient mixes	Flour Composition	Appearance	Colour	Texture	Taste	Overall acceptability
Control	WW	8.60±0.07	8.70±0.08	8.60±0.10	8.70±0.06	8.65 ^a
1	WW+Mb+Fl+Fn	4.70±0.62	4.20±0.60	6.70±0.50	7.20±0.68	5.725 ^{fg}
2	WW+Bar+Mb+Fl+Fn	7.10±0.30	6.60±0.38	8.10±0.20	8.00±0.38	8.150 ^{bc}
3	WW+Bar+Mb+Fl+Fn	3.60±0.40	3.10±0.41	5.60±0.43	6.10±0.42	4.600 ^{kl}
4	WW+Ot+Mb+Fl+Fn	3.60±0.47	3.10±0.46	5.60±0.43	6.10±0.43	4.600 ^{kl}
5	WW+Ot+Mb+Fl+Fn	3.40±0.35	2.90±0.30	5.40±0.35	5.90±0.20	4.450 ^l
6	WW+Cp+Fl+Fn	3.50±0.41	3.00±0.40	5.50±0.45	6.00±0.44	4.575 ^{kl}
7	WW+Bar+Cp+Fl+Fn	7.30±0.30	6.80±0.33	7.90±0.33	7.80±0.39	8.300 ^{bc}
8	WW+Bar+Cp+Fl+Fn	4.10±0.73	3.60±0.70	6.10±0.75	6.60±0.74	5.150 ^{hij}
9	WW+Ot+Cp+Fl+Fn	4.00±0.76	3.50±0.66	6.00±0.71	6.50±0.56	5.075 ^{hijk}
10	WW+Ot+Cp+Fl+Fn	4.10±0.85	3.60±0.75	6.10±0.85	6.60±0.55	5.125 ^{hij}
11	WW+Bg+Fl+Fn	8.20±0.26	8.50±0.25	8.50±0.11	8.20±0.21	8.35 ^{ab}
12	WW+Bar+Bg+Fl+Fn	5.60±0.66	5.10±0.50	7.60±0.45	8.50±0.54	6.650 ^d
13	WW+Bar+Bg+Fl+Fn	3.70±0.36	3.20±0.30	5.70±0.31	6.20±0.35	4.725 ^{ijkl}
14	WW+Ot+Bg+Fl+Fn	3.60±0.43	3.10±0.40	5.60±0.41	6.10±0.42	4.675 ^{ijkl}
15	WW+Ot+Bg+Fl+Fn	3.70±0.43	3.20±0.30	5.70±0.35	6.20±0.45	4.775 ^{ijkl}
16	WW+Sb+Fl+Fn	5.00±0.84	4.50±0.76	7.00±0.56	7.50±0.65	6.050 ^{ef}
17	WW+Bar+Sb+Fl+Fn	5.00±0.84	4.50±0.84	7.00±0.80	7.50±0.76	6.050 ^{ef}
18	WW+Bar+Sb+Fl+Fn	5.00±0.55	4.50±0.44	7.00±0.65	7.50±0.12	6.050 ^{ef}
19	WW+Ot+Sb+Fl+Fn	6.90±0.22	6.400.21	8.00±0.44	7.80±0.75	7.975 ^c
20	WW+Ot+Sb+Fl+Fn	5.30±0.21	4.80±0.22	7.30±0.43	7.80±0.71	6.350 ^{de}
21	WW+SM+Fl+Fn	4.20±0.77	3.70±0.71	6.20±0.65	6.70±0.23	5.225 ^{ghi}
22	WW+Bar+SM+Fl+Fn	4.40±0.77	3.90±0.71	6.40±0.61	6.90±0.55	5.475 ^{gh}
23	WW+Bar+SM+Fl+Fn	4.20±0.67	3.70±0.61	6.20±0.22	6.70±0.65	5.200 ^{hi}
24	WW+Ot+SM+Fl+Fn	4.10±0.80	3.60±0.75	6.10±0.80	6.60±0.70	5.125 ^{hij}
25	WW+Ot+SM+Fl+Fn	3.90±0.69	3.40±0.45	5.90±0.60	6.40±0.50	4.975 ^{hijk}

Whole wheat: WW; Barley: Bar; Oats: Ot; Mungbean: Mb; Cowpea: Cp; Bengal gram: Bg; Soybean: Sb; Skimmed milk powder: SM; Flaxseeds: Fl; Fenugreek seeds: Fn) CD at 5 % = 0.524

Values are Mean SD ^{a-l} Means within each row with different superscripts are significantly ($P < 0.05$) different

had fibre content comparable to the control whereas, noodles made up of ingredient mixes 2, 7 and 19 were having significantly ($p \leq 0.05$) increased fibre content than the control. High fibre is reported to have hypocholesterolemic effect, hence ingredient mixes are specifically suited for metabolic syndrome patients. The highest crude protein was found in bread prepared from ingredient mix 16, followed by ingredient mix 2, 7 and 8, however, crude protein content did not vary significantly in these four ingredient mixes. In extruded snack and noodles, all the products were having significantly higher protein than their control counterparts. Studies have reported that addition of soy flour to bread products can raise protein content, balance essential amino acids, and increase bread's nutritional value (Riaz 1999). Previous studies have reported that a portion of wheat flour can be

substituted with mungbean flour to obtain high-protein noodles. Vijaykumar et al. (2010) studied the influence of pulse flour blend on physical, nutritional, cooking and organoleptic characteristics of noodles prepared from composite flour of millet flour blend, whole wheat flour and soy flour and reported that 20 % level of millet and soy blend incorporation was found to be highly acceptable. Similar results were shown by Mitra et al. (2012) demonstrating that the enrichment of white salted noodles with oat flour would provide a potential health benefit due to increased protein content. Studies have also reported that fortification with milk proteins results in acceptable extrusion of snack foods (Tunick and Onwulata 2006; Day and Swanson 2013).

All the products prepared from the ingredient mixes showed a significantly lower ($p \leq 0.05$) carbohydrate content

Table 5 Proximate composition and in vitro protein digestibility of developed products on dry weight basis

Ingredient mixes	Flour composition	Moisture(%)	Total ash(%)	Crude fibre(%)	Crude fat(%)	Crude protein(%)	Carbohydrates(%)	In vitro protein digestibility (%)
Bread								
2	WW+Bar+Mb+Fl+Fn	1.8 ^{ab} ±0.1	2.3 ^a ±0.1	2.3 ^{ab} ±0.3	3.2 ^b ±0.3	21.2 ^{ab} ±1.1	69.2 ^c ±0.2	82.4 ^{cd} ±1.5
6	WW+Cp+Fl+Fn	1.7 ^b ±0.2	2.3 ^a ±0.4	2.6 ^a ±0.6	4.2 ^a ±1.7	19.6 ^{bc} ±1.4	69.6 ^{bc} ±1.8	83.4 ^{bcd} ±1.4
7	WW+Bar+Cp+Fl+Fn	1.9 ^{ab} ±0.6	2.2 ^{ab} ±0.2	2.5 ^a ±0.4	3.1 ^b ±1.3	21.0 ^{abc} ±0.6	69.3 ^c ±2.0	82.2 ^d ±1.7
8	WW+Bar+Cp+Fl+Fn	1.8 ^{ab} ±0.2	2.2 ^a ±0.3	2.4 ^a ±0.7	3.0 ^b ±1.1	20.8 ^{abc} ±0.3	69.8 ^{bc} ±0.9	77.1 ^c ±2.7
11	WW+Bg+Fl+Fn	1.8 ^{ab} ±0.4	2.4 ^a ±0.4	1.9 ^{ab} ±0.1	2.6 ^{bc} ±0.9	19.5 ^c ±1.1	71.8 ^b ±0.9	86.2 ^{ab} ±1.8
16	WW+Sb+Fl+Fn	1.7 ^b ±0.1	2.4 ^a ±1.0	2.0 ^{ab} ±0.1	3.0 ^b ±0.8	22.3 ^a ±0.8	68.6 ^{bc} ±1.1	85.6 ^{abc} ±1.7
Control	WW	2.4 ^a ±0.4	1.3 ^c ±0.3	1.6 ^b ±0.1	2.4 ^{bc} ±0.6	9.5 ^d ±0.6	82.8 ^a ±0.8	87.0 ^a ±1.5
CD [•]		0.6	0.9	0.7	0.8	1.6	2.2	3.2
Extruded snacks								
2	WW+Bar+Mb+Fl+Fn	2.4 ^a ±0.2	3.0 ^b ±0.4	2.7 ^a ±0.1	2.8 ^a ±0.4	21.0 ^b ±0.2	68.0 ^{bc} ±0.9	78.1 ^b ±1.7
11	WW+Bg+Fl+Fn	2.4 ^a ±0.3	3.3 ^b ±0.0	2.1 ^a ±0.0	3.0 ^a ±0.8	19.4 ^c ±0.5	69.7 ^b ±1.0	81.5 ^{ab} ±2.6
13	WW+Bar+Bg+Fl+Fn	2.2 ^a ±0.2	3.2 ^b ±0.0	2.2 ^a ±1.5	2.6 ^a ±0.0	19.2 ^c ±1.0	70.4 ^b ±2.3	80.9 ^{ab} ±1.5
22	WW+Bar+SM+Fl+Fn	2.4 ^a ±0.4	3.2 ^b ±0.2	1.8 ^a ±0.0	3.0 ^a ±1.5	23.1 ^a ±0.8	66.4 ^c ±2.9	82.1 ^{ab} ±2.4
Control	WW	1.5 ^b ±0.3	4.2 ^a ±0.1	1.7 ^a ±0.2	1.6 ^a ±0.3	9.2 ^d ±0.3	81.5 ^a ±0.4	83.8 ^a ±3.1
CD [•]		0.5	0.4	1.2	1.4	1.1	3.2	4.3
Noodles								
2	WW+Bar+Mb+Fl+Fn	2.5 ^a ±0.3	2.3 ^{ab} ±0.2	2.5 ^{ab} ±0.5	3.0 ^a ±0.5	21.1 ^a ±1.0	68.4 ^b ±0.5	79.6 ^b ±0.7
7	WW+Bar+Cp+Fl+Fn	2.1 ^{ab} ±0.3	2.3 ^a ±0.5	2.5 ^{ab} ±0.1	3.2 ^a ±0.5	20.8 ^a ±1.5	68.9 ^b ±2.3	76.7 ^c ±1.4
11	WW+Bg+Fl+Fn	2.3 ^{ab} ±0.1	2.3 ^a ±0.5	2.1 ^{bc} ±0.5	2.8 ^{ab} ±0.5	20.1 ^a ±1.5	70.3 ^b ±2.9	81.0 ^{ab} ±2.1
19	WW+Ot+Sb+Fl+Fn	2.1 ^{ab} ±0.4	2.3 ^a ±0.5	2.9 ^a ±0.5	2.0 ^{bc} ±0.5	19.6 ^a ±1.5	71.0 ^b ±2.5	80.0 ^{ab} ±1.3
Control	WW	1.8 ^b ±0.3	1.4 ^b ±0.3	1.7 ^c ±0.2	1.7 ^c ±0.2	10.5 ^b ±1.0	82.7 ^a ±0.5	82.8 ^a ±1.9
CD [•]		0.5	0.8	0.7	0.8	2.4	3.7	2.8

Values are expressed as mean SD, [•] Significant at 5 %

Whole wheat: WW Barley: Bar; Oats: Ot; Mungbean: Mb; Cowpea: Cp; Bengal gram: Bg; Soybean: Sb; Skimmed milk powder: SM; Flaxseeds: Fl; Fenugreek seeds: Fn)

^{a-c} Means within each row with different superscripts are significantly ($P<0.05$) different

against control i.e. 68.6 to 71.8 against 82.8 % in bread, 66.4 to 70.4 against 81.5 % in extruded snack and 68.4 to 71 against 82.7 % in noodles. All the breads prepared from selected ingredient mixes had significantly higher fat content. However, the chemical composition of the ingredients in the mixes indicated a high proportion of poly unsaturated fats which have reported benefits for hyperlipidemic patients.

In vitro protein digestibility is very important in accessing the quality of protein in a given product. It also helps to assess the effect of any processing effort on the same (Ayo et al. 2007). In vitro protein digestibility of bread prepared from ingredient mixes 11 and 16 was comparable with the control. Rest of the breads were having slightly lower digestibility. Extruded snack prepared from ingredient mixes 11, 13 and 22 and noodles prepared from ingredient mixes 11 and 19 were having comparable protein digestibility than their

corresponding control. Degen et al. (2007) reported that soluble fibre reduced the apparent and true ileal digestibility of proteins and amino acids. Hence, foods rich in fibre might help in reducing the symptoms of hypercholesterolemia due to decreased digestibility. Though all the mixes were significantly superior in most of the nutritional components, the higher digestibility in ingredient mix 11 and 16 from bread; 11, 13 and 22 from extruded snack and 11 and 19 from noodles make them nutritionally most suitable for bread, extruded snack and noodle making, respectively.

Lysine, a limiting amino acid in wheat flour was significantly ($p\leq 0.05$) higher in all the products as expected due to the addition of pulse flours in the proportions to correct the amino acid score up-to 100 in all the ingredient mixes. Lysine content increased from 599 to 704 mg/100 g in bread, 682 to 782 mg/100 g in extruded snack and 607 to 989 mg/100 g in

Fig 1 Lysine content of the breads, extruded snacks and noodles made from selected ingredient mixes (mg/100 g dry weight)

noodles in comparison to their corresponding control samples i.e. 299, 314 and 285 mg/100 g, respectively (Fig. 1). The nutritional value of protein-containing food is not only dependent on the quantity and digestibility of the protein, but also the amino acid composition and availability of essential amino acids (Day and Swanson 2013). Wheat-flour protein quality can be improved by addition of protein supplements, which are high in lysine. Since legume proteins both complements the amino acid profile of cereal protein and are economical, it has considerable potential for improving the nutritional status of large populations of people who depend on cereal-based diets (Riaz 1999).

The study concluded that six ingredient mixes of breads and four ingredient mixes each of extruded snack and noodles specifically designed for MS patients were organoleptically at par with control wheat flour products. The selected products

were significantly high in protein, fibre, ash and low in carbohydrates. The *in vitro* protein digestibility was comparable to their control counterparts. The developed functional products showed improved protein quality through enhanced lysine content. These functional foods may contribute to alleviate MS but certain aspects like impact of supplementation of these foods to MS patients needs further investigation.

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