Compositional profiling and sensorial analysis of multi-wholegrain extruded puffs as affected by fructan inclusion

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Revised: 17 October 2014 / Accepted: 3 November 2014 / Published online: 19 November 2014
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Abstract Rice grits, corn grits, pulse, wholegrain - finger millet and sorghum were utilized in the production of multi-grain extruded puffs using a single screw extruder. The effect of inclusion of fructan - fructoligosaccharide in multi-wholegrain (MWG) extruded puffs was examined. MWG fructan enriched puffs had 450 % higher dietary fiber content than the control puff (CP). These puffs can be categorized as ‘Good Source’ of fiber as it suffices 17.2 % DV of fiber. Puffs were rated 8.1 ± 0.6 , 8.3 ± 0.7 , 8.1 ± 0.6 , 7.5 ± 0.5 and 8.2 ± 0.6 for color, flavor, texture, appearance and overall acceptability respectively. The scores for all the attributes were found to be not significantly different ($p < 0.05$) from CP. The MWG fructan puffs were rated higher on flavor than the CP having a score of 8.3 ± 0.7 as opposed to 8.2 ± 0.4 for CP. This indicates that the nutritional quality and acceptability of MWG extruded puffs could be improved by the inclusion of fructans.

Keywords Extrusion · Proximate composition · Sensory analysis · Snack · Fiber

Introduction

Extrusion cooking is a modern, high temperature, short-time processing technology to manufacture snack foods (White 1994). Food extruders provide thermo-mechanical and mechanical energy (shear) necessary to cause physicochemical changes of raw materials with an intense mixing for dispersion

and homogenization of ingredients including conveying, mixing, shearing, heating or cooling, shaping, venting volatiles and moisture, flavor generation, encapsulation, and sterilization (Linko et al. 1981; Wiedman and Strobel 1987). Extruded foods are composed mainly of cereals, starches, and/or vegetable proteins. The major role of these ingredients is to give structure, texture, mouth feel, bulk, and many other characteristics desired for specific finished products (Launay and Lisch 1983; Jamora et al. 2002; Tahnoven et al. 1998). These snacks generally lack dietary fiber.

Snack food extrusion includes subjecting selected grains to a variety of complex physical processes to yield snacks with varied shapes and textures (White 1994). Different types of snack foods are available of which the new generation snacks fall into several categories such as low fat, baked but not fried, high fiber products made from pure dietary fiber and natural fiber from wholegrain etc.

Consumer acceptance of extruded snack foods is mainly due to the convenience, value, attractive appearance and texture found to be particular for these foods, especially when it concerns to snack products (Harper 1981). The success or failure of a new extruded snack food product is directly related to sensory attributes, where texture plays a major role (Pamies et al. 2000). Together with the sensory attributes, today's consumers are also looking at the nutritional aspects of these snack foods. The demand for healthier snack foods is on the rise.

In the midst of the current debate on functional foods and the proven health effects of fructans, it is important that food manufacturers and retailers introduce new products with added health benefits in the market. In the food industry, inulin or fructo-oligosaccharides from chicory (*Cichorium intubus*) roots or Jerusalem artichoke (*Helianthus tuberosus*) tubers are being utilized to optimize the quality of diet. Inulin and fructoligosaccharide (FOS) have been classed as functional food ingredients (Arai 2002). Inulin is a polydisperse β (2–1)

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fructan. The degree of polymerization (DP) is in the range of 2 to 60. The low molecular weight fractions of inulin (DP 2–20) are known collectively as FOS. These have been generally recognized as safe (GRAS) by FDA. From an analytical and a physiological point of view both inulin and FOS have been classed as dietary fibers (Coussement 1999). They meet the analytical definition of dietary fiber used by AOAC (Report 2001).

Due to the non digestibility of inulin and FOS, they are found to be suitable for consumption by diabetics (Yamashita et al. 1984; Rumessen et al. 1990). Inulin and FOS have been termed “prebiotics” (Gibson et al. 1995) because they are non digestible food ingredients that selectively stimulate growth of health-stimulating intestinal bacteria such as *bifidobacteria* (Bouhnik et al. 2004; Wiele et al. 2007). The caloric value of inulin and FOS is estimated to be 1.0 and 1.5 kcal/g respectively (Roberfroid 1999). They can be used for either their nutritional advantages or technological properties, but they are often applied to offer a dual benefit: an improved organoleptic quality and a better-balanced nutritional composition (Coussement 1999).

Extruded snacks/puffs presently available in the market are mainly refined grain based such as corn and rice and thus lack dietary fiber. These puffs are mainly fried in nature and contain very high amount of fat (upto 30 %). The present study aimed to develop multigrain, fiber enriched, low calorie extruded puffs using wholegrain together with fructan. Finger millet is rich in calcium and dietary fiber. Sorghum is rich in iron and fiber. These are nutritious millets known for their health benefits. But the coarse texture of these grains limits their application. Using soluble fiber - fructan (fructooligosaccharide) is one way to reduce gritty texture because they are more palatable. Direct puffing technology which totally eliminates the frying operation in snack production has been utilized for the production of puffs. The novel feature of the products is that these are not only low calorie but also contains dietary fiber both soluble and insoluble.

Thus, in the present research the concept of optimal nutrition, by way of introduction of functional ingredients in the extruded puffed snacks has been addressed. The imperative sensorial properties and proximate composition which are decisive to the acceptability of extruded puffs have been investigated.

Materials and methods

Single screw extrusion of multi-wholegrain puffs

A tailor made single screw extruder with a capacity of up to 25 kg (G.L. Extrusion System Private Limited, Delhi, India) founded on direct expansion technology was used for production of puffs. The standard formulation for control puff

included rice grits: corn grits: green gram pulse in the ratio of 80:10:10. Rice (*Oryza spp.*) grits and corn (*Zea mays*) grits (bag size of 50 kg each) were procured from Ahaar Consumer Products (P) Limited, Lawrence Road, Delhi, India. The specifications of the product included description of the raw material, sensory characteristics, physicochemical specification and particle size distribution. Green gram pulse was procured locally and was standardized as per Prevention of Food Adulteration Act (PFA), 1955. All raw material including rice grits, corn grits, green gram pulse, finger millet and sorghum were analysed for proximate composition using standard AOAC 2005 procedures. Extrusion of control puffs (CP) was carried out at a temperature of 110 °C. Extrudates were cylindrical puffs. The diameter of the extrudates varied between 12.5 and 13.5 mm whereas the length varied between 27.9 and 29.3 mm. Extrudates were spread on perforated aluminum trays and dried in an air oven maintained at 100 °C for 15 min to moisture content of 2.5–3 %.

Multi-wholegrain (MWG) puffs were developed using wholegrain millets-finger millet and sorghum by successively replacing rice and corn grits. Finger millet (*Eleusine coracana*) and Sorghum (*Sorghum vulgare*) were purchased locally and were standardized as per IS 4333 (Part I and II): 1996 specification “Method of Analysis for food grains”. All puffs were prepared in a batch size of 4 kg. Temperature for extrusion of multi-wholegrain (MWG) puff was standardized at 110 °C in relation to optimum expansion. Extrudates were spread on perforated aluminum trays and dried in an air oven maintained at 100 °C for 15 min to moisture content of 2.5–3 %.

MWG puffs with 20 % finger millet and 30 % sorghum were enriched with fructan (FOS) at 10 and 15 % levels. FOS (Beneo Raftilose® P95, Orafit, Belgium, U.K) was procured from DPO Food Specialities Pvt. Ltd, Thane, Maharashtra, India. Beneo Raftilose P95 is a powder containing mainly oligofructose produced by partial enzymatic hydrolysis of chicory inulin. It is a food ingredient composed of oligofructose, fructose, glucose and sucrose. The total number of fructose or glucose units (=Degree of Polymerization or DP) of oligofructose ranges mainly between 2 and 8. The technical specifications of FOS are provided in Table 1. FOS was incorporated at the initial blending (preconditioning) stage together with other raw materials. The temperature for extrusion of FOS enriched multigrain puff was standardized to be 130 °C. Extrudates were spread on perforated aluminum trays and dried in an air oven maintained at 100 °C for 15 min to moisture content of 2.5–3 %. Extrusion could be effectively undertaken with 10 % FOS level whereas with 15 % level some complexity was encountered in running the extruder, as FOS is hygroscopic in nature and because of intense heat the likelihood of charring enhances. Therefore, inclusion of FOS in MWG puffs was limited to 10 % level. Figure 1 illustrates control puffs, multi-whole grain puffs and multi-whole grain puffs with fructan.

Table 1 Technical specifications of FOS (Beneo Raftilose® P95)

Parameter	Analysis
Oligofructose	≥93.2 %
Glucose+fructose+Sucrose	<6.8 %
Carbohydrate	>99.5 %
Caloric value	1.5 Kcal/g
Degree of polymerization (DP)	2–8
Appearance	Fine white Powder
Taste	Slightly sweet, without after taste
Behaviour	Hygroscopic
Dispersability in water	Excellent
Solubility in water	>750 g/l
Density	Approx. 700±70 g/l

Orafti, Belgium, U.K

Packaging of extruded puffs

All puffs were packed in 20 g three layered metallized pouches (procured from Jain Flexipack Private Limited, Azadpur, Delhi, India) comprising of the top layer made up of polyester film (12 µm thick) printed on reverse having a grammage of 16.8 g/m², the middle layer was made up of plain metallized polyester film having a grammage of 16.8 g/m² laminated to the top layer with the help of 2 µm adhesive layer and the third layer made up of low density polyethylene (LDPE) film plain (30 µm thick) having a grammage of 27.9 g/m² laminated to middle layer with the help of 2 µm adhesive layer. Packaged puffs were stored at ambient temperature until needed for nutritional and sensorial analysis.

Fig. 1 Control puffs, multi-whole grain puffs and multi-whole grain puffs with fructan

Compositional profiling of extruded puffs using standard analytical methods

Complete compositional profiling of the CP and MWG fructan enriched puff was undertaken as follows:

Fat, protein, moisture, ash and carbohydrate content

Fat content was determined using soxhlet extraction, protein using Kelvac (Kes 12 l) Nitrogen Estimator (Pelican Equipments, India), moisture by air oven method (IS 1011 2002), and ash using IS 1011:2002. Carbohydrate content was calculated by the difference.

Dietary fiber and fructan estimation

The total dietary fiber was estimated by AOAC 991.43:2005 method Total fructan content of the products and fructan content of corn and rice grits, sorghum, finger millet and green gram pulse were determined by AOAC 999.03:2005 enzymatic spectrophotometric method using Megazyme K-Fruc Kit, Ireland.

Fatty acid profiling including trans fat using Gas Chromatography

Fatty acid profile of the puff fat was determined using Report 2001 method as protocol based on Gas Chromatography. From this the *trans* fat content was estimated.

Minerals - calcium and iron estimation by AAS

Calcium and iron content of puffs was estimated using atomic absorption spectrophotometer (SPECTRAA - 220 FS from Varian, Inc.).

Caloric value of puffs

Caloric value of puffs was estimated using Atwater factors by multiplying the proportion of protein, fat and carbohydrate by their respective physiological fuel values of 4, 9 and 4 kcal/g and taking the sum of all the products. FOS calorific value was taken as 1.5 kcal/g.

Sensorial analysis of extruded puffs

Sensorial analysis of extruded puffs was performed by a twenty five member untrained panel consisting of postgraduate students of the Department of Foods and Nutrition, Lady Irwin College, University of Delhi, New Delhi, India. The panelists, aged between 18 and 22 years, were regular consumers of extruded puffs. Hedonic sensory attributes evaluated in this study were colour, texture, flavour, appearance and overall acceptability (OAA) of extruded puffs. A 9 point hedonic scale anchored by “dislike extremely” and “like extremely” was employed (Amerine et al. 1965). Session was conducted at room temperature in a sensory room equipped with white fluorescent lighting. The panel session was held mid-morning, about 4 h after breakfast. Puffs were served in bowls to panelists. Samples were provided randomly to the panelists. Sensory evaluation procedures were explained to the panelists before testing commenced. Sensory evaluation score cards were prepared and panelists were asked to read through the instructions and the questions on the sensory form and the meaning of each attribute was explained to the panelists to avoid misinterpretation. The panelists were given time to ask for clarification of the sensory evaluation procedure when uncertain or unclear about the process. Water at room temperature was provided to rinse the mouth between evaluations. A panelist score of 7 or higher (like moderately) given

to the product was considered as a sign of acceptability (Chavez-Jauregui et al. 2003). Mean $\pm$ SD scores of panelists for each variant of extruded puffs were estimated.

Statistical analysis

Analysis of variance (ANOVA) with the least significant difference test (LSD-test) was applied. The level of significance used was 95 % ($p < 0.05$). All the statistical analysis was performed using software SPSS 16.0 for windows version. For the graphical treatment data was imported into graphics package of MS Excel.

Results and discussion

This paper caters to today's consumer need for healthy natural ingredients with higher nutritional-physiological values and the expected taste enjoyment in snacks. The various sensory qualities attributes of snack foods like appearance, texture, taste, color and flavour together with compositional profiling were addressed in the current research.

Compositional profiling of raw material for extruded puffs

The results of the compositional profiling of raw material are presented in Table 2. The fat content of rice grits was found to be 0.004 % while that of corn grits was estimated to be 2.1 %. The protein content of rice and corn grits was comparable. The total dietary fiber content of rice and corn grits was estimate to be 3.3 and 3.8 % respectively. The fructan content of rice grits (0.35 %) was found to be higher than that of corn grits (0.15 %). The protein content of green gram pulse was estimated to be 23.2 %. The total dietary fiber and fructan content were estimated to be 8.4 and 2.0 % respectively. The fat content of finger millet was found to be 1.3 % while that of sorghum was estimated to be 1.6 %. The protein content of finger millet was found to be lower than that of sorghum. The

Table 2 Compositional profile of the raw material for puffs (%)[#]

Proximate composition	Rice grits	Corn grits	Green gram pulse	Finger millet	Sorghum
Protein	10.1	9.8	23.2	7.4	10.5
Carbohydrate	73.5	70.9	49.7	64.1	63.0
Fat	0.004	2.1	1.1	1.3	1.6
Total dietary fiber	3.3	3.8	8.4	11.2	9.9
Fructan	0.35	0.15	2.0	0.3	0.6
Ash	0.3	0.4	3.4	2.8	1.8
Moisture	12.5	12.9	12.2	12.9	12.6

[#] Results are expressed as mean of three determinations

Table 3 Compositional profile of extruded puffs[#]

Nutrition facts	CP (per 100 g)	MWG fructan enriched puff (per 100 g)	MWG fructan enriched puff (per serving =30 g)	MWG fructan enriched puff (% DV) ^a
Energy, Kcal	388	352	106	
Protein, g	11.4	11	3.3	6.6 %
Carbohydrate, g	76.4	65.6	19.7	5 %
Total Fat, g	4	4	1.2	0.8 %
Saturated Fat, g	0.6	0.6	0.2	0.04 %
<i>Trans</i> Fat, g	0	0	0	
Monounsaturated Fat, g	2.3	2.3	0.7	
Polyunsaturated Fat, g	1.1	1.1	0.3	
Ca, mg	21	71	21	2.1 %
Fe, mg	1.3	2.6	0.8	4.4 %
Total Dietary Fiber, g	1.8	8.2	2.5	
Insoluble Fiber, g	1.2	6.6	2.0	
Soluble Fiber, g	0.6	1.6	0.5	
FOS (Fructan), g	0.8	6.1	1.8	
Total Fiber, g	2.6	14.3	4.3	17.2 %

[#] Results are expressed as mean $\pm$ SD of three determinations

^a Percent DV are based on a 2000 cal diet

values obtained were 7.4 and 10.5 % respectively. The total dietary fiber content of finger millet and sorghum was estimated to be 11.2 and 9.9 % respectively. Thus, finger millet was found to contain higher total dietary fiber than sorghum. The fructan content of sorghum (0.6 %) was found to be higher than that of finger millet (0.3 %) (Table 2).

Compositional profiling of extruded puffs

The compositional profiling of the CP and the final MWG fructan enriched puff is presented in Table 3. The USP of MWG fructan enriched extruded puff is as follows:

- Total dietary fiber including oligofructose is 450 % higher than the control puff.
- Carbohydrate content is 14.1 % lesser than the control puff.
- Calorie content is 9.3 % lesser than the control puff.
- Iron content of multigrain puff is 100 % higher than the control puff.
- Calcium content of multigrain puff is 238 % higher than the control puff.

As per FDA a food to be labeled as ‘Good Source’ of particular nutrient should provide 2.5 to 4.9 g/serving i.e. 10 to 19 % of DV and as ‘High Fiber’ or an ‘Excellent Source’ should provide 5 g and above/serving i.e. 20 % or more of DV. Based on these criteria MWG fructan enriched puff can be categorized as ‘Good source’ as it suffice 17.2 % DV of fiber.

Also products to be labeled as ‘Low’ in a particular nutrient should provide 5 % or less of the DV. The carbohydrate content of MWG fructan enriched puff can be categorized as

‘Low’ as they will suffice for only 5 % of the DV. However, FDA doesn’t authorize a ‘Low’ nutrient content claim for carbohydrates. Secondly these puffs can be categorized as ‘Low’ in fat as these would provide only 1.2 g total fat per RACC and only 0.2 g saturated fat per RACC. As per FDA foods to be labeled as ‘Low’ in fat and ‘Low’ in saturated fat should provide 3 g or less of total fat and 1 g or less of saturated fat per RACC respectively.

Sensorial analysis of extruded puffs

Table 4 shows the sensorial score ratings on a nine point hedonic scale of all the formulations of extruded puffs. The results of analysis revealed that CP (Sample 1) was rated

Table 4 Sensory evaluation scores ($n=25$) of extruded puffs[#]

Sample†	Color	Flavor	Texture	Appearance	OAA
1(Control)	8.4 $\pm$ 0.7	8.2 $\pm$ 0.4	8.3 $\pm$ 0.5	8.0 $\pm$ 0.7	8.4 $\pm$ 0.5
2	8.0 $\pm$ 0.7	8.1 $\pm$ 0.6	8.0 $\pm$ 0.7	7.8 $\pm$ 0.6	8.1 $\pm$ 0.7
3	8.0 $\pm$ 0.7	7.9 $\pm$ 0.6	8.0 $\pm$ 0.7	7.8 $\pm$ 0.6	8.0 $\pm$ 0.7
4	7.9 $\pm$ 0.8	7.8 $\pm$ 0.8	7.8 $\pm$ 0.8	7.7 $\pm$ 0.7	7.8 $\pm$ 0.4
5	7.4 $\pm$ 0.7*	7.6 $\pm$ 0.5*	7.7 $\pm$ 0.7*	7.5 $\pm$ 0.7	7.7 $\pm$ 0.8*
6	7.4 $\pm$ 0.7*	7.6 $\pm$ 0.7*	7.7 $\pm$ 0.5*	7.5 $\pm$ 0.7	7.7 $\pm$ 0.5*
7	7.0 $\pm$ 0.7*	6.8 $\pm$ 0.6*	7.5 $\pm$ 0.7*	6.6 $\pm$ 0.7*	6.9 $\pm$ 0.7*
8	8.1 $\pm$ 0.6	8.3 $\pm$ 0.7	8.1 $\pm$ 0.6	7.5 $\pm$ 0.5	8.2 $\pm$ 0.6

[#] Results are expressed as mean $\pm$ SD scores on 9 point hedonic scale

* Significantly different from control ($p<0.05$)

† Sample 1 (control) contains no finger millet, sorghum or fructan, Samples 2–7 contains finger millet and sorghum in varied proportion and no fructan, Sample 8 contains finger millet, sorghum together with fructan

Fig. 2 Sensory evaluation scores ($n=25$) of control, MWG and MWG fructan enriched puffs on 9 point hedonic scale

higher on attributes like color, texture, appearance and overall acceptability by the panelists. The color and OAA components were rated highest amongst all with scores of 8.4 ± 0.7 and 8.4 ± 0.5 respectively on a nine point scale. The ANOVA results indicated that all the components of sensory evaluation were not significantly affected till 10 % finger millet and 30 % sorghum incorporation level. Above this level color, flavor, texture and OAA for all MWG puffs were found to be significantly different ($p < 0.05$) from the control. The OAA mean score rating for 20 % finger millet and 30 % sorghum inclusion level (Sample 6) was 7.7 ± 0.5 on a nine point scale. The sample with 30 % finger millet (Sample 7) was rated slightly below the 'like moderately' cutoff of 7, having an OAA score of 6.9 ± 0.7 on a nine point scale.

MWG fructan enriched puff (Sample 8) was rated 8.1 ± 0.6 , 8.3 ± 0.7 , 8.1 ± 0.6 , 7.5 ± 0.5 and 8.2 ± 0.6 for color, flavor, texture, appearance and OAA respectively (Table 4). The scores for all the attributes were found to be not significantly different ($p < 0.05$) from CP. The OAA score of 8.2 ± 0.6 for MWG fructan enriched puff (Sample 8) was close to the OAA score of 8.4 ± 0.5 for the CP. The MWG fructan enriched puffs (Sample 8) were rated higher for flavor than the CP having a score of 8.3 ± 0.7 as opposed to 8.2 ± 0.4 for control puff. This indicates that the acceptability of multigrain puffs could be improved by the incorporation of fructan (FOS). This better acceptability of MWG fructan enriched puffs could be attributed to their improved texture and flavor as FOS has ability to blend with other fibers to create a bland flavor profile (<http://www.orafti.com>). Oligofructose contributes towards improved mouthfeel (Crittenden and Playne 1996), which could have lead to improved scores for texture of puffs. Also, the use of inulin or oligofructose as a fiber ingredient has been stated to lead to an improved taste and texture (Franck and Coussement 1997).

MWG fructan enriched puffs (Sample 8) was rated 8.1 ± 0.6 , 8.3 ± 0.7 , 8.1 ± 0.6 , 7.5 ± 0.5 and 8.2 ± 0.6 for color, flavor, texture, appearance and OAA respectively. The corresponding MWG puff (Sample 6) had mean scores of 7.4 ± 0.7 , 7.6 ± 0.7 , 7.7 ± 0.5 , 7.5 ± 0.7 and 7.7 ± 0.5 for color, flavor, texture, appearance and OAA respectively (Table 4). Thus, MWG fructan enriched puff was rated higher for all the attributes as compared to corresponding MWG puff without FOS. Therefore, incorporation of FOS led to better acceptability of MWG puffs. Spider plots visualizing the relative sensory scores of CP, MWG puffs and MWG fructan enriched puffs are shown in Fig. 2.

Conclusions

Inclusion of fructan provided improved desirable sensory/organoleptic characteristics to the limited palatability of wholegrain snacks. The acceptability of these products was increased further by improving the nutritional contour principally the dietary fiber content (both soluble and insoluble) since low fiber consumption has been implicated as a risk factor in many diseases. Thus, such extruded snack foods can be used as a convenient vehicle to the overall success of a functional food because of their popularity amongst subjects. This research provides the health conscious individuals with a healthier snack option over the regular refined grain snack - A multi-wholegrain, novel functional fiber enriched extruded snack.

Acknowledgments The cooperation of the human subjects who participated in the study is gratefully acknowledged. This study was supported by research grant from University Grants Commission (UGC), New Delhi, India.

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