Gluten free approach in fat and sugar amended biscuits: A healthy concern for obese and diabetic individuals

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Abstract
Flour premix of copra meal 15% with germinated foxtail millet 85% blended with amaranth in 60:40 proportions to get gluten free, calorie deficient composite mix for biscuits. Attempts were made for obese and diabetics as target population with maltodextrin and acesulfame-k to find the extent of possible partial replacement of bakery fat and table sugar, respectively. It was found that substitution feasibility to 48% fat and 47% sugar lie within the acceptable limits of physical and sensorial properties comparable to control sample. Successful calorie reduction in fat and binary (fat and sugar) amended biscuits were achieved to 364.58 kcal/g and 315.97 kcal/g, respectively, as in comparison with control (471.01 kcal/g). Low anti-nutrients (phytate and tannin) and increased polyphenols in biscuits is a function of germinated foxtail millet. Acrylamide development also restricted to 0.193 μg/g in sugar replaced and 0.32 μg/g in sugar and fat replaced biscuits comparable to control (0.5 μg/g).

Practical applications
Copra as by-product from coconut industry is rich in fiber and protein but still restricted to as livestock feed till date. Its utilization for human is itself a novel approach. Standardized inclusion of copra meal to selected nutritious gluten free grains reveals a healthy budgetary option. Further, intentional substitution of dense calorie compounds (fat and sugar) with their calorie deficit counterpart to target obese and diabetic along with celiac is investigated. Owe to protein richness of selected coarse cereal varieties and copra, huge malnourished population may easily access pseudo cereal and coarse cereal based composite food with enhanced health attributes.

1 | INTRODUCTION

Now a days market has grand range of foods that are varied by appearance, taste, and nutrition. Selection preferences among huge mass of consumer for these eatables largely depend on their food habits and health concern. Availability of nutraceutical and functional foods in each segment (beverage, baked, and fermented) is on preference side that adapt globally and even the research is being continuously executed in the same direction to explore more healthy options. Binge eating and their ill effects also advised keen interest of researchers to design and formulate nutritious, functional, probiotics, and value added composite foods. These above stated variety of foodstuff are still calorie dense as a consequence part owe to utilized fat or sugar in any form. Food tailoring, addition and replacement of these components with their counterpart provides a healthy decision applicable to composite dairy cereal blend (Aggarwal, Sabikhi, & Sathish, 2015) and baked goods, respectively (Zoulias, Spyros, & Vassiliki, 2000). High fat intake coupled with obesity which in turn increases risk for high blood pressure, coronary heart disease, and cancer (Mackay, Mensah, Mendis, & Greenlund, 2004). Similarly high dietary sugar intake in day to day life leads to chronic diseases like diabetes (Hu, 2011). As an estimate prevalence of diabetes among adults (aged 20–79 years) will be 439 million by 2030. Between 2010 and 2030, there will be 69% rise in diabetic population in developing countries and 20% increase in developed countries (Shaw, Richard, & Paul, 2010).

Baked foods viz. buns, bread, biscuits, cakes, muffins, and pastries have frequent consumption pattern by each income class under any age group population. Acceptability of these foods generally decided by its taste, flavor, and their appearance in which sugar and fat is of main concern. Dense fat and sugar utilization expected to have elevated sensory properties, that is, appearance, texture, taste, and mouthfeel value but avoided by health conscious population. An
advisable alternative against these components which add functionality to the final product includes polysaccharides with low dextrose equivalent (DE), gums, pectin, and inulin that is fiber enriched meant for fat replacement (Roberfroid, 2004). Intense sweeteners and polyols used as sugar replacer to maintain low glycemic index and to avoid becoming diabetics (Livesey, 2003). Possibilities for replacement of dense calorie can be done through artificial/natural sweeteners like aspartame, acesulfame-k, sugar alcohols, stevia, and so forth. Some investigations with acesulfame-k due to its heat stable, intense sweetness, calorie deficient, and water solubility characteristics grant its suitability for baked formulations (Chattopadhyay, Raychaudhuri, & Chakraborty, 2014). Similarly reduction in fat is counter balanced by bulking agents, thickening agents, for example, starches, dextrins, maltodextrin, olestra, egg white, and so forth (Napier, 1997). Maltodextrin is water soluble with low DE value, “GRAS” labeled and white crystalline powder (Sudha, Vetrimani, & Leelavathi, 2006), used as texture modifier for retention of water and for substitution of fat in various baked applications (Topaloglu, 2015). Correspondingly acesulfame-k is a well known intense sweetener with sweetening intensity of 200 times than that of table sugar (Parker, Salas, & Nwosu, 2010) and is approved by Food Safety and Standards Authority of India (FSSAI) to be use in baked and confectionary with maximum daily intake of 9 mg/kg of body weight (Chaudhary, 2015). Various frozen or heat based baked, confectionary, and drink formulations justify its application without any loss of sweetening intensity (Fitch & Keim, 2012). Textural development of baked goods is a function of basic bakery specified ingredients, that is, flour, water, sugar, and fat (Pareyt & Delcour, 2008).

As per the literature pertaining to gluten free biscuits formulation and then its optimization with sugar and fat replacers, limiting studies were evidenced. Present investigation focused to optimize the formulation with acesulfame-k and maltodextrin as sugar and fat replacer, respectively, thus add a new and healthy choice in the series of commercially available baked goods meant for celiac, obese, and diabetics sufferers.

2 | MATERIALS AND METHODS

2.1 | Materials used

Raw foxtail millet seeds were procured from Indian Institute of Millet Research, Rajendranagar, Hyderabad of Telangana (India). These seeds were treated with Thiram (fungicide) for their safe storage and advised to wash before their utilization. Amaranth seeds (Amaranthus hypochondriacus) were purchased from local market of Kurukshestra, Haryana. Copra meal was obtained from local trader in Kollam, Kerala. Maltodextrin (DE < 20) is white crystalline powder, as an option to replace bakery fat was obtained from Titan Biotech, Mumbai. Similarly white crystalline powder of acesulfame-k procured from Kawarlal and Company, Chennai. Both the ingredients were approved for their use in foods and have generally recognized as safe status.

2.1.1 | Preprocessing of raw material

Raw seeds of foxtail millet and amaranth were washed separately in potable running water to remove fungicide and adhered extraneous matter (dust and dirt). Foxtail millet seeds are phytate prominent so allowed to pass through minimal preprocessing treatments of soaking (overnight) followed with germination to minimize these antinutrients (Yamasaki, 2003). Soaking for whole night in fresh water with 0.1% formaldehyde restricts mould growth which is then incubate at 25°C / 24–48 hr in plastic trays bedded with moistened muslin cloth (Singh & Nathan, 2014a, 2014b) resulted in emerged rootlets of about 1–2 mm. Germinated seeds are then allowed to dry at 55°C to the remaining moisture of 12%, followed by removal of dried rootlets through rubbing against mesh screen. These seeds were milled and sieved through 60 mesh sieve size to remove 5% coarse bran. Amaranth grains were then dried to 14% moisture level followed by grinding and sieving through 60 mesh sieve size to remove 5% coarse bran. Copra meal need just milling to copra meal flour through Sujata grinder at lab scale and sieved with 60 mesh sieve. Guar gum (Sigma-Aldrich, St. Louis, MO) was utilized for proper binding and consistency of dough, in lieu of nonavailability of gluten in composite mix (Gallagher, Gormley, & Arendt, 2004).

2.2 | Recipe for biscuit preparation

2.2.1 | Ingredients proportion

Premix is a combination of pretreated 55 g foxtail millet flour (FMF) with 10 g copra meal flour; proportion of this premix blend (60 g) further mixed with 40 g amaranth flour (AF) to have composite flour mix. Listed ingredients utilized per 100 g of composite flour mix basis were as follows; 32 g sugar, 42 g fat, and 4.0 g SMP along with water (35 ml). Other additives utilized in biscuit formation are baking powder, table salt, and guar gum (1 g each), ammonium bicarbonate (0.75 g) and 1 ml cardamom flavor common for both control and test sample of biscuits. Test sample of biscuits varied in water proportion to that of control sample for their optimum consistency as per the amended counterpart (acesulfame-k and maltodextrin).

2.2.2 | Biscuit preparation steps

Homogenous stirred creamy of bakery fat poured with powdered sugar within agitation steps followed with intermittent addition of calculated amount of lukewarm water amalgamated with guar gum. Inclusion of composite flour at this stage with extended mixing (3 min) ended with due amount of salt and leavening agent dissolved water. Addition of essence improves the degree of likeness through flavor contribution. The prepared mass of dough after refrigeration for about 30 min at 4°C sheeted to 1 cm thickness with the aid of wooden rolling pin and then mold cut to 5 cm diameter. Baking tray with this mold cut dough is then subjected to baking in preheated deck oven at 180°C / 15 min.

2.3 | Descriptive trials for optimization of additives

Concentration of fat and sugar replacer was optimized on physical, chemical, and sensorial basis. Bakery fat adjustment with maltodextrin through replacement trials in range of 5–35 g was done for total of 42 g of fat utilized in control sample. Fat optimized mix is further
investigated to replace table sugar with acesulfame-k in 3 steps of replacement trials with 10, 15, and 20 g out of total 32 g sucrose utilized.

2.4 Evaluation of biscuits

2.4.1 Sensory analysis

Consumer acceptance test was carried out with 9-point hedonic scale from a group of 12 selected nonallergic regular consumers of biscuits. The samples were evaluated by assigning numeric code for each group of test and control samples. Sensory judgment is a function of following attributes viz. appearance, hardness, flavor, and overall acceptability (Meilgaard, Carr, & Civille, 2006).

2.4.2 Textural study

Textural value of baked goods calculated in the form of hardness or cutting strength subjected to HDP/BSW (Heavy duty platform/Bratzler blade) set of texture analyzer from Stable Micro System T2i (UK), with preset profile of pretest speed, test speed, and post-test speed of 2.5 mm/s, 2 mm/s, and 10 mm/s, respectively (Pareyt et al., 2009).

2.4.3 Proximate characterization

Control and test sample of biscuits were evaluated for proximate composition, using Association of Official Analytical Chemists AOAC procedures, 1990 and 2010 (AOAC, 1990).

2.4.4 Energy calculation

Total energy of sample was calculated by the addition of carbohydrate, protein, and fat contained and multiplying them with their respective energies (Acheson, Campbell, Edholm, Miller, & Stock, 1980).

2.4.5 Spread ratio

Spread ratio of baked biscuits was determined by dividing average value of width by average value of thickness of biscuits. It is a functional value depends on amount of fat contained in it (Sudha, Srivastava, Vetrimani, & Leelavathi, 2007). Sheeted round biscuits of equal thickness with 4 cm diameter were tested after baking for their difference in spread ratio in comparison with control sample of biscuits by digital vernier scale using formula.

\[ \text{Spread ratio} = \frac{\text{Width (mm)}}{\text{Thickness (mm)}} \]

2.4.6 Color value

Color of prepared biscuits evaluated for all test and control group using colorflex colorimeter. Baked biscuits on fine crushing were placed into the respective glass bowl and color values were noted after its calibration with white and green tiles (Hunter Associated Laboratory, Inc., VA). Presented as L* (Lightness +100 or whiteness −100), a* (Redness +60 or greenness −60), and b* (yellowness +60 or blueness −60) with D65 chrome using view angle of 10°.

2.4.7 Chemical evaluation

Biscuits were explored by chemical means such as polyphenols and antioxidant capacity in them through Folin-Ciocalteu reagent (Singleton, Orthofer, & Lamuela-Raventos, 1999) and DPPH, respectively (Velasquez, Tourier, Mordujovichte, Saadeva, & Scinella, 2003). These were also evaluated against a series of tests for various antinutrients viz. tannins, phytate, and acrylamide present in flour and prepared samples, respectively.

Phytate was estimated through Megazyme phytic acid kit. Acidified methanol extracted sample was subjected to color development using kit content (buffers, enzyme suspensions, ammonium molybdate, and vitamin C). Reaction terminated through trichloroacetic acid solution (50% w/v), centrifuged at 13,000 rpm, supernatant was observed spectrophotometrically at 655 nm against water as blank.

Tannins were estimated using vanillin assay method with tannic acid as standard (Singh & Hathan, 2014a, 2014b). Extraction of sample was done in 70% acetone, boiling of extracted sample resulted in color development for about 60 min and read against blank at 500 nm.

Detection of acrylamide was done through standardized procedure of extraction and analysis from baked samples (Khoshnam, Zargar, & Parham, 2010). Four grams of ground samples were weighed into flask. 10 ml of hexane was added with shaking for 5 min to remove fat. Then mixture was dried under vacuum, after decantation. Addition of another 10 ml of hexane, shaking and decantation was done for further removal of fat from samples. After its drying, 20 ml of acetone and 100 μl of water added to the defatted samples for the extraction of acrylamide. Ultrasonication of samples was done in water bath at 40°C for about 20 min. Filtration of samples was done through filter paper. 10 ml of the filtrate was evaporated and dried. Then, 2 ml of water was added and shaken thoroughly to dissolve the residues. The aqueous solution was filtered through filter paper.

Acrylamide detection was done through LC-18 column of high performance liquid chromatography (Shimadzu, Japan). Mobile phase selected was Acetonitrile: HPLC grade Water (70:30) with flow rate of 0.5 ml/min and detection wavelength set to 202 nm, operated on isocratic mode with 20 μl sample injection (Singh & Raja, 2010).

2.4.8 Statistical analysis

Data collected were subjected to analysis of variance (ANOVA). All values are means of triplicate determinations ± standard deviation using Statistical Package for the Social Sciences (SPSS) version 16.0. Graph pad prism (Version 5.0) is utilized for proximate and chemical characterization using one way ANOVA to evaluate significance of the data.

3 RESULTS AND DISCUSSION

3.1 Standardization of level with maltodextrin as fat replacer

Preliminary trials with maltodextrin as counterpart for fat with various ratios were selected. Selection of series of successive trials in a replacement range (5–35g) was analyzed sensorially. It was found that biscuits with 20 g replacement of bakery fat with maltodextrin got highest score as evident from the Table 1. This replacement contributes % reduction in fat as 48%.
Sensory score of control, fat replaced, fat and sugar replaced biscuits

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Sensory score of control, fat replaced, fat and sugar replaced biscuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Hardness</td>
</tr>
<tr>
<td>Control</td>
<td>7.66 ± 0.02</td>
</tr>
<tr>
<td>Fat replaced</td>
<td>6.2 ± 0.5</td>
</tr>
<tr>
<td>Fat &amp; sugar replaced</td>
<td>6.0 ± 0.5</td>
</tr>
<tr>
<td>15M:27BF</td>
<td>5.7 ± 0.5</td>
</tr>
<tr>
<td>25M:12BF</td>
<td>5.6 ± 0.2</td>
</tr>
<tr>
<td>15M:7BF</td>
<td>5.5 ± 0.3</td>
</tr>
<tr>
<td>30M:18BF</td>
<td>5.3 ± 5.7</td>
</tr>
<tr>
<td>5M:37BF</td>
<td>5.0 ± 0.1</td>
</tr>
</tbody>
</table>

All values are means of triplicate determinations ± standard deviation. Means within the same row are significantly different (p < .05). Where M = maltodextrin; BF = bakery fat.

3.2 | Standardization of level of acesulfame-k as sugar replacer

To study the binary effect, optimized fat replaced biscuits (48% reduced) were then followed to explore their possibility with acesulfame-k as sugar replacer (Forker, Susann, & Harald, 2012). To evaluate the possibility of partial replacement of table sugar with acesulfame-k as preliminary trial on w/w basis, 10, 15, and 20 g of table sugar compensate with 0.05, 0.075, and 0.1 g of acesulfame-k, respectively, out of a total of 32 g sugar proportion. These sugar replacement trials contribute % reduction in sugar as 31%, 47%, and 62%, respectively. This calculated amount was creamed with fat along with replacers. Increase in % proportion of acesulfame-k resulted in alteration of physical functionality or disturbed workability of dough. Reduction of sugar more to 47% resulted in cracked texture with hard bite.

As per the sensory records for the previous trials (Table 1), fat replaced (20g or 48% reduced bakery fat) and binary replaced (sugar and fat) biscuits (15 g or 47% reduced sugar) suits competitively to selected panel of judges on 9-point hedonic scale. These optimized values of fat and sugar counterpart do not allow further extended replacement beyond standardized limit otherwise biscuits with cracked texture, hardness with less spreadability will results.

3.3 | Sensory analysis

Liking preference on 9-point hedonic scale for baked biscuits in comparison with control sample was conducted on 12 researchers as shown in Table 2. It follows the sequence as given below:

Control > Fat replaced > Fat & Sugar replaced

Sugar replaced biscuits follows almost the common trend of likeness comparable to control as thus favors the findings investigated by Taylor, Fasina, and Bell (2008). Similar findings of textural desirability in terms of mouthfeel reported by Zoulias, Oreopoulou, and Tzia (2002) in continuation with sugar and fat replacer biscuits concern against control group, favors maximally in the same trend as shown below.

3.4 | Proximate analysis

Table 3 state that samples with fat replaced biscuits have least amount of fat (13.52 ± 0.02) among all the samples studied which is attributed mainly to its replacement with the utilized fat mimetic, that is, maltodextrin. Non-nutritive sweeteners are calorie deficient (47.73 ± 0.05) and that of other samples ranged in-between 50.25 ± 0.17 and 54.65 ± 0.05. Protein restricts its value in the range of 12% for all the samples studied. Control sample is on least side thus contribute none significantly in the form of burnt ashes but maltodextrin addition raises the level of it comparable to control group as shown in Figure 1. Fat and sugar replaced biscuits were entrapped with high moisture than control owe to availability of hygroscopic nature of maltodextrin to bind moisture in them (5.49 ± 0.03) (Chronakis, 1998).

3.5 | Energy evaluation

Artificial sweeteners do not contribute any calorie to the body. Maltodextrin is also calorie deficient thus both test samples viz. fat replaced and binary (fat and sugar replaced) biscuits impart 364.58 kcal and 315.97 kcal, respectively. These samples were deficient in energy.
when evaluated against control group of dense calorie biscuit, that is, 471.01 kcal.

### 3.6 | Spread ratio

Biscuits were explored morphologically for spread ratio (cm) that favor negatively with maltodextrin in comparison with control sample (4.04 ± 0.25). Maltodextrin in fat replaced biscuits limit its value to 3.68 ± 0.01 while the sample with binary replacers (fat and sugar) found to have spread ratio of 3.57 ± 0.01. Spread ratio is a function of available water and fat that melts and extends favorably at the time of baking. Proportion of fat (%) component get reduced in test sample with maltodextrin thus restricted mass of fat is allowed to spread while maltodextrin do not behave as like fat and resulted in compact structure of baked biscuits and it is in similar to the findings as investigated and suggested by Pareyt et al. (2009).

### 3.7 | Color analysis

Colorimetric observation using hunter color lab in the form of \( L^* \), \( a^* \), and \( b^* \) value for baked biscuits were studied in 5 replicate and presented as average in Table 4 and compared. \( a^* \) and \( b^* \) value do not varied as much but significant difference in \( L^* \) value comparable to control indicates lessens caramelization in fat replaced and binary (fat and sugar) replaced biscuits than to the control one, probably due to the nonavailability of sugar units meant for soothe caramelized appearance of baked samples.

### 3.8 | Chemical analysis

Phytate and tannin contents were in between 0.027–0.031 g/100 g and 1.30–1.35 mg/100 g, respectively (Figure 2). These concentrations are far less than the lethal concentrations of phytates and tannins with respect to permissible human intake (Kaur, Jha, Sabikhi, & Singh, 2014). Least concentration of it never pose any threat in bioavailability of proteins that prove the agreement quoted by Kumari, Krishnan, Jolly, and Sachdev (2014), although germination followed by baking has significant effect to minimize these antinutritional constituents. Almost resembled data for antioxidant scavenging capacity is in direct influenced with available phenolics hence results shows that germinated foxtail millet flour was the causative agent that lowers anti-nutrients,

### TABLE 3 Proximate characterization of baked biscuits

<table>
<thead>
<tr>
<th></th>
<th>Fat replaced (%)</th>
<th>Fat &amp; sugar replaced (%)</th>
<th>Control (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>5.11 ± 0.02</td>
<td>5.49 ± 0.03</td>
<td>4.18 ± 0.04</td>
</tr>
<tr>
<td>Protein</td>
<td>12.4 ± 0.03</td>
<td>12.1 ± 0.03</td>
<td>12.34 ± 0.03</td>
</tr>
<tr>
<td>Fat</td>
<td>13.52 ± 0.02</td>
<td>14.33 ± 0.06</td>
<td>18.01 ± 0.11</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>50.25 ± 0.17</td>
<td>47.73 ± 0.05</td>
<td>54.65 ± 0.05</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>15.09 ± 0.04</td>
<td>16.51 ± 0.03</td>
<td>8.07 ± 0.03</td>
</tr>
<tr>
<td>Ash</td>
<td>3.63 ± 0.02</td>
<td>3.84 ± 0.04</td>
<td>2.75 ± 0.10</td>
</tr>
</tbody>
</table>

All values are means of triplicate determinations ± standard deviation. Means within the same row are significantly different (\( p < .05 \)).
raises polyphenols and antioxidant capacity as well (Singh & Nathan, 2014a, 2014b). Statistical analysis (one-way ANOVA; p < .05) of control and treated sample of biscuits revealed nonsignificant differences in the observed values of these components.

Formation of acrylamide during baking was also taken into consideration and detected in comparison with standard’s chromatogram. Control sample have constituents of asparagine amino acid and reducing sugar hence appear with larger peak area whose concentration rely on higher side (50 μg/100 g) as in comparison with test sample of fat replaced and binary (fat and sugar) replaced samples to 19.3 μg/100 g, and 32 μg/100 g, respectively. Contrary findings of acrylamide formation while thermal application of test and control samples were due to nonavailability of components that initiates the chemistry of acrylamide formation on heating. It was investigated and evaluated by Gokmen, Ozge, Hamit, and Jale (2007), likewise where sugar presence has pronounced effect in acrylamide formation and its replacement counteract it.

3.9 | Textural analysis

Hardness of biscuits for test and control both were explored where control biscuit required (48.26 ± 0.02 N m⁻²) of breaking force comparable to that of fat replaced with (52.02 ± 0.26 N m⁻²) thus little hard as in comparison with control group, binary group of biscuits (fat and sugar) replaced need 54.34 ± 0.04 N m⁻² breaking force. This increase in breaking strength in fat and sugar amended baked biscuits is in corroboration with the previous reports of Banerjee, Verma, and Gore (2015), where much proportion of fat get replaced with maltodextrin hence decrease in fat directly approaches toward the hard characteristics of baked goods.

4 | CONCLUSION

It can be concluded from the present investigation that gluten free by-product based baked food with replaced sugar and fat counterpart will work as a remedy for individuals, allergic to wheat and its interbreed species. Acesulfame-K and maltodextrin may be exploited as alternatives to avoid the risk of calorie imbalance in obese and diabetic persons thus will lead to addition of one more consumers segment. Reduction of acrylamide production in amended biscuits is another promising feature that is generally ignored in every of functional food formulation studies, hence enhances the status of present research work.

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