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Effect of Fat Replacers on the Multigrain Biscuits

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Abstract: Nowadays, people are concerned about their health due to the change and modification in lifestyle. People demand a ready to eat food products that are healthy and safe. Biscuits or cookies are the most consumed snack product that gives feeling of fullness for the hunger between two meals and also liked by the every age group people. But the bakery fats and shortenings that are used in the preparation of biscuits, contain trans fatty acids that are not good for health. In this study, biscuits were formulated with multigrain flour (refined wheat flour, barley flour and corn flour) in pre-defined ratios using fat replacers to reduce the fat content and hence trans fatty acid content. Two types of fat replacers i.e. Polydextrose(PD) and whey protein concentrate (WPC) were used to replace the fat content of biscuits from 10-50%. On the basis of organoleptic quality analysis and physicochemical analysis, the biscuit sample in which 40% shortening was replaced by equal proportion of polydextrose and whey protein concentrate (WPC) was found optimum. So, this study suggest that fat can be reduced or partially replaced up to 40% by using PD and WPC without much change in the sensory and physical characteristics.

Keywords: Biscuits, Fat Replacers, Multigrain Biscuits, Polydextrose, Trans Fatty Acid, Whey Protein Concentrate

1. INTRODUCTION

Modern lifestyle has become the most adaptive nature of today's world and people. Lifestyle modification is necessary for a better change from the people's health point of view. But, the modern lifestyle has both pros and cons in the food industry. It provides us awareness about nutrition and healthy food, packaged food for easy portability and accessibility, and ready-to-use foods for less time consumption. Whereas, sometimes people only depend on it and tend to eat more junk food than fresh food, which gives the body more calories and non-nutritive

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components. An unhealthy diet rich in calories and saturated fat, along with physical inactivity, leads to non-communicable diseases like obesity, diabetes, etc., in the body.

However, people are now more conscious about calorie intake and try to maintain proper nutrition in meals for morning and night. But for the snack food items, people don't take anything properly and do not get more nutrients. For this reason, the food industry is focusing on the production of low-fat/low-calorie, high-fiber foods. Biscuit is the most eatable snack in most countries because of its nutritional value, ready-to-eat nature, easy availability, and affordable cost [1]. The health-promoting effect of biscuits can be increased by using several fat replacers and multigrain flour to make it more acceptable for health-conscious, diabetic, and every person to get more nutrients and less fatty daily snack food.

To make a multigrain biscuit more nutritious in terms of fiber and carbohydrates, various combinations of flours were used with wheat flour to make it a multigrain biscuit. Generally, biscuit industries are facing a problem of the nutritional value as the biscuit is low in protein quantity (6-7 %) and quality as deficient with the essential amino acid lysine[2],[3]. Hence, to improve the nutritional status of biscuits, there is a need to incorporate some protein-rich material in biscuits, which will help in elevating the protein level in the biscuits and improve the protein quality of biscuits by providing lysine and other essential amino acids. In terms of reducing fat, fat replacers were used to partially replace the fat, making it a low–calorie biscuit.[1]

The multigrain biscuit was prepared from the partial replacement of the refined wheat flour with barley flour and corn flour. Barley is said to be a functional grain because it contains B-complex, beta-glucan, vitamins, tocopherols, and tocotrienols and has significant antioxidant potential. Some studies have also shown that barley flour has a high content of dietary fiber and a high proportion of soluble fiber especially beta-glucan. Beta-glucan is suggested to lower plasma cholesterol, reduce glycemic index, improve lipid metabolism, and boost the immune system. The insoluble fiber present in barley helps in reducing the risk of colon cancer [4]. That is the reason why it is becoming an important cereal from the nutritional and functional point of view. Various experiments have shown that barley can be successfully incorporated into multiple products such as different types of bread, bars, muffins, Asian noodles, biscuits and cookies [4],[5]. Corn consists of active functional food ingredients, such as fiber (dietary fiber), carbohydrates, anti-oxidants and minerals that are not composed of Fe sorghum and wheat [6].

Polydextrose (PD) and Whey Protein Concentrate (WPC) are the two of the most popular carbohydrate and protein-based fat replacers, respectively. Polydextrose is known as a complex carbohydrate made from glucose, citric acid, and sorbitol, which forms a highly viscous gel-like matrix contributing to the creaminess and mouth-feel [7]. Various forms of attempts had already been made to replace fat in the biscuits by the use of fat mimetics like polydextrose, maltodextrin, dairy trim, pectin, and Simplesse® [8]. The combination of fat replacers like corn fiber, maltodextrin or lupine extract [9], maltodextrin and guar gum [10], etc.
Previously, whey was treated as a waste product because of its potential for spoilage and storage. However, nowadays, it is no longer treated as a waste product but as a treasure of

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nutritionally rich whey proteins (11). the quality of whey protein is said to be superior because of the vital essential amino acid profile, protein biological, and value efficiency ratio[12]. The food manufacturing industry has come to realize that whey proteins have the potential to improvise the quality status of food products due to various functional properties such as solubility, viscosity, water binding, whipping, emulsification and gelation [13],[14],[15].

It is helpful in diabetes, cardiac problems, antihypertensive, liver ailment, gout and arthritis. It also performs as a sports food as WPC helps in the repair of injured and torn muscle during various sports practices and activities [16],[17]. WPC gives excellent nutritional values in nutrition foods formulated for infants to old-aged people as a growth tonic for body health maintenance [18].

More of the formulation of products with acceptable properties could only be achieved when partial, instead of full, replacement of fat was used. Reduction in fat beyond 30–40% resulted in higher hardness, firmness, and breaking strength of cookies [8],[19].

The objective of this study was to make a low-fat, multigrain biscuit using multigrain flour [comprises refined wheat flour (RWF), Barley flour (BF), and corn flour (CP)] partial replacement of fat up to 50% by using two types of fat replacers; carbohydrate-based fat replacer- Polydextrose (PD) & protein based fat replacer- Whey protein concentrate(WPC) to make it a low calorie and high nutritional value snack item.

The purpose of the above study present study was to improve the nutritional status of biscuits by incorporating fat replacers affecting the overall quality of the biscuits.

2. MATERIALS AND METHODS

2.1 Raw materials and ingredients

Raw materials selected were refined wheat flour (*shaktibhog brand*), barley flour (*curry patta brand*), Corn flour (*tops brand*), white butter (*from local dairy*), sugar, polydextrose (*Japtose's brand*), whey protein (*big flex essential brand*).

2.2 Preparation of control biscuits

According to Aggarwal *et al.*. [1] and Das *et al.* [20], the control sample of multigrain biscuit was prepared using the traditional creaming method. Firstly, the fat (50 gm) was creamed and mashed finely using Hobart Mixer at variable speeds until its volume doubled. And then, pre-blended sugar (30 gm) was added until the creaming was done completely. Various formulations were made by using different ratios of three flours. One of the optimized biscuit formulation was opted, which included refined wheat flour (40gm), barley flour (35gm) and corn flour (25 gm) were homogeneously mixed with the addition of sodium bicarbonate (1.5 gm) and then added to the above creamed mixture and mixed to get a crumbly texture. The required amount of water (approx.. 30 ml) was gradually mixed into the mixture to prep*are* a soft dough. Then the dough was rolled into a thin uniform sheet with a thickness of 5 mm. Then, the biscuits were cut in a circular shape using a round biscuit cutter of 5.3 cm diameter from the dough sheet. Then the biscuits were baked at 180 C upper and 140 C lower

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temperatures for 20 minutes using the baking oven. The freshly baked biscuits were cooled at room temperature and were packed in airtight packets for storage for further use.

2.3 Formulation and preparation of low-calorie biscuits using fat replacers

Polydextrose (PD) and whey protein concentrate (WPC) were chosen as fat replacers to reduce the fat content from control multigrain biscuits. PD was used because of its bulky and fat-sparing quality. Also, it provides only 1kcal/g and whey protein concentrate has a very low calorific value of 2 cal/g[1].

Both ingredients were added in the dry form with the above ingredients of control multigrain biscuits.

Five formulations of butter, polydextrose and whey protein were made using design expert software version13 and D-optimal mixture design. While the two, polydextrose and whey protein concentrate, were constant with each other but varied with the fat composition as the fat percentage varied in each sample from 90% to 50%. Each sample has 3 triplicates at least. The values are expressed as mean ±standard deviation. The other ingredients were same as in the control biscuits except for fat content. (Table 1)

After getting a suitable formulation, the two fat replacers were added in the above preparation process of control biscuits. The overall preparation process for the preparation of the fat–replaced biscuits is given in Figure 2.

Table 1: Formulations of fat–replaced multigrain biscuits

Sample no.	Fat reduction %	FAT (g)	PD (g)	WPC (g)	Composite flour (RWF + BF + CF :: 40+35+25) (g)	Sugar (g)	Baking Powder (g)	Water (ml)
CONTROL	-	50	-	-	100	30	1.5	30
SAMPLE 1	10	45	2.5	2.5	100	30	1.5	30
SAMPLE 2	20	40	5	5	100	30	1.5	30
SAMPLE 3	30	35	7.5	7.5	100	30	1.5	34
SAMPLE 4	40	30	10	10	100	30	1.5	36
SAMPLE 5	50	25	12.5	12.5	100	30	1.5	40

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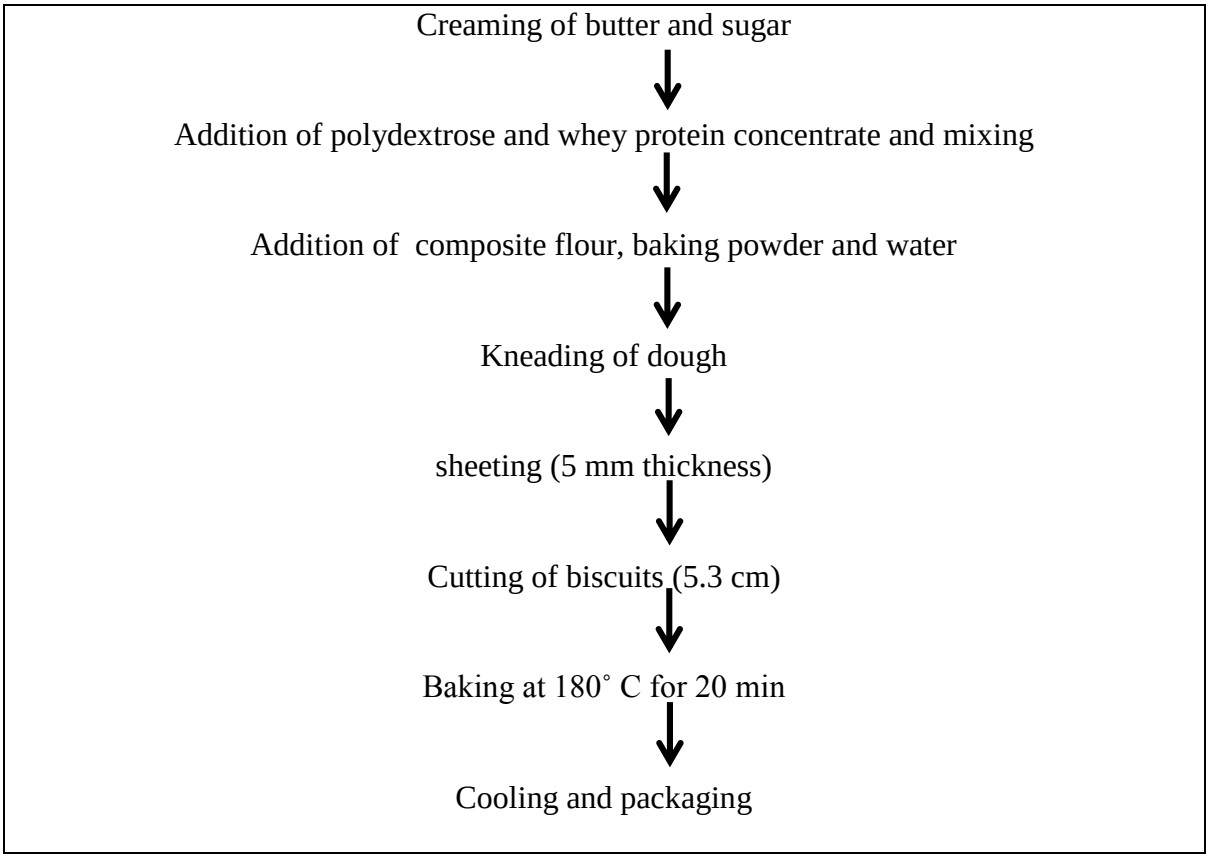

Fig. 1 Flowchart of the preparation process of fat replaced multigrain biscuits

2.4 Optimization of fat replacer biscuits

2.4.1 Physical analysis

Thickness, diameter, spread ratio and % spread factor of biscuits were measured and calculated. The Spread ratio was determined by dividing the average diameter value by the average thickness value. The spread factor was calculated by dividing the spread ratio of test biscuit by the spread ratio of control biscuit *100 [21]. To measure the weight (g) of the biscuit, the digital weighing balance was used. Slide caliper measured the Diameter (cm) and Thickness (cm). The TA-XT2 Texture Analyser (Stable Micro Systems, Godalming, Surrey, UK) was used to analyze dough texture following method given in Sudha *et al.*[19].

2.4.2 Physiochemical analysis

The Proximate nutritional composition of biscuits are Moisture percent, Acid insoluble ash percent, Fat percent, Protein percent, and Crude fiber percent of biscuits were analyzed as per standard methods given in the FSSAI standard lab manual 3[22].Carbohydrate content was calculated by allowing subtraction techniques mentioned by [23] as carbohydrate = 100 – (protein + fat + ash + moisture content + fiber). Each analysis was performed in triplicate.

2.4.3 Sensory analysis

Sensory parameters like color, taste, texture, flavor, and overall acceptability were evaluated by the method given in Ranganna (2005) [24]. A semi-trained jury of 10 panelists assessed

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for freshly baked biscuit samples containing various proportions of ingredients for their sensory attributes. The 9-point hedonic rating test was used for the sensory evaluation of biscuits. For each sample, panelists were asked to scored their liking of these characteristics of biscuits using the Nine-point Hedonic Scale (1 – dislike extremely, 2 – dislike very much, 3 – dislike moderately, 4 – dislike slightly, 5 – neither like nor dislike, 6 – like slightly, 7 – like moderately, 8 – like very much, and 9 – like extremely) [25]. And one-way ANOVA was used to assess the extent of acceptance at a significance level of 5% ($p \leq 0.05$).

2.4.4 Statistical analysis

The various analyses were done in triplicate and the obtained data were analyzed statistically using mean and standard deviation and the online calculation (internet) to perform the analysis of variance (ANOVA). The treatments were considered as non-significantly different at a 5% level of significance, i.e., p>0.05

3. RESULTS AND DISCUSSION

3.1 Physical analysis of fat replaced multigrain biscuits

The physical analysis of control multigrain biscuits and developed low-calorie biscuits is shown in Table 2.The diameter and thickness of the biscuits do not differ significantly ($p>0.05$) with the reduction of fat and sugar content, but the addition of the polydextrose and whey protein concentrate resulted in a slight increase in thickness. The highest diameter was found in the control sample (5.4 cm), and the lowest diameter was shown by a 50% fat reduction in sample 5 (5.2cm).

Table 2: Physical analysis of fat replaced multigrain biscuits

Sample	Diameter (cm)	Thickness (cm)	Spread ratio	Spread factor (%)	Dough hardness (gm)
Control	5.4±0.04	1.14±0.03	4.73±0.18	100.00±0.03	3025.4
Sample 1	5.3±0.03	1.00±0.02	5.30±0.15	112.05±1.32	3254.7
Sample 2	5.3±0.02	0.95±0.03	5.57±0.22	117.75±2.15	3148.1
Sample 3	5.2±0.04	0.96±0.02	5.41±0.12	114.37±3.41	2641.2
Sample 4	5.3±0.02	1.04±0.02	5.09±0.18	107.61±2.75	2232.5
Sample 5	5.2±0.03	1.02±0.01	5.09±0.21	107.61±2.13	2136.2

Values are expressed as mean±standard deviation of triplicate testing. Sample means values do not differ significantly at a 5%level of significance (p>0.05)

It was also observed that the reduced diameters for all samples were closer to controlled biscuits. Thickness was highest in the case of control sample (1.14 cm), whereas Sample 2 showed the lowest thickness value (0.95 cm). However, it gradually increases as the level of PD and WPC increases in samples 4 and 5. A similar study was shown in [18] and [26]. Spread ratio is said to be an essential parameter of biscuit consistency, non-significantly ($p>0.05$) influenced by the reduction of fat and sugar. Spread ratio was in the increased order with the decrease in fat and sugar value, while with the addition of PD and WPC, there was a slight decrease in spread ratio. The spread ratio was greater in sample 2 and lesser in control;

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similar findings were given in [26]. It is probable that increasing amount of polydextrose and whey protein resulted in rising in spread ratio but also, as thickness increases it can be seen that the spread ratio decreases [18]. However, the differences in the sizes of baking and mould conditions may be responsible for the difference in thickness, diameter, and spread ratio, values with that reported by other authors [26**].** Considering the spread factor of control multigrain biscuit (100%), it increases as spread ratio and decreases with the value of spread ratio.

Replacement of fat by 10% level with PD and WPC, the fat–replaced biscuit dough did not show much effect on the dough hardness as measured in the texture analyzer (Table 2) as compared to the control dough hardness. However, when fat was replaced by 40% and 50% in sample 4 and sample 5, respectively, there was a decrease in dough hardness was observed. A similar study was found by Aggarwal *et al.*.[[1]

3.2 Physiochemical analysis of fat replaced multigrain biscuits

The protein, fat carbohydrate and fiber content for raw material given by the supplier are as follows : RWF (12.45%, 0.58%, 76.62%, 2.97%,); for barley (22%, 1.2%, 63%, 14%); for corn (4%, 0%, 96%, 0%); for WPC (80%, 7.4%, 0%,0%,); for PD (4%, 23%, 3%, 27%).

3.21 Moisture

The moisture content of the developed biscuit samples ranged as 2.43 –4.20% (Table 3). The moisture content of the control biscuit was 3.27%. It has been observed that moisture value was decreased slightly with the fat and sugar reduction, while adding polydextrose and WPC results in an increment of moisture content. This is due to the higher water holding capacity of PD because polymers such as xanthan gum, CMC, polydextrose, maltodextrin, etc., have high water empathy and can maintain moisture in foods [27]. Also, incorporating WPC in dough required excess water than the control dough to make it workable in terms of consistency [18]. Therefore the moisture of all the PD & WPC fortified biscuits was slightly greater than control biscuits. Developed biscuits have moisture content closely related to [28], which showed similar moisture content in biscuits as 2.56 - 3.42%. Aggarwal *et al.*.[1] gives the idea of the moisture range of 4.16- 4.30 present in the multigrain biscuit incorporated with PD and Simplesse®.

3.22 Protein

The protein content values were found in the range of 7.56 – 13.64 %. Protein content was increased significantly with the reduction of fat and sugar accordingly. Control biscuits have the lowest (7.569%) protein, while sample 5 had the highest protein (13.648%). Also, it was observed that the protein content increased proportionately with an increasing level of WPC incorporated. The protein values were found to be similar in the study of Munaza *et al.*. [23], Parate *et al.*.[18]. Hence, the protein contents in the prepared biscuits were in agreement with the protein contents of the biscuits reported by the other workers.

3.23 Fat

Analysis of fat gives the value range of 22.757 – 14.560% in the samples (Table 3). The highest fat content was present in the control sample (22.757%) and the lowest in Sample 5 (14.560%). The replacement of fat content with gradual increase of PD & WPC results in the

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gradual reduction in the fat content. Finally, it leads to lowering the maximum 36.01% fat in the final sample than control. Aggarwal *et al.*. [1]recorded 21.5% fat in control biscuits and 14.1% low-calorie biscuits made with a similar approach.

3.24 Ash

The ash content of biscuit samples was in the range of 1.31 - 1.67%. Evaluation of the ash content gives the value for sample 5 as the highest (1.67%), and sample 2 showed the lowest ash content (0.84%), while the control samples gave the 1.31% of ash content. The ash content of the biscuits increased slightly with the addition of fat replacers like PD and WPC in samples 4 and 5. It is due to WPC, which has a high content of minerals [23] accordingly, Aggarwal *et al.*. [1] recorded ash content for control is 1.68 % and 1.93% for an optimized biscuit. So, it was concluded that the ash content of developed biscuits was closer to the above mentioned ranges.

3.25 Crude fiber

The fiber content ranged from 3.81- 5.78%. A gradual increase was observed in the crude fiber content of the developed biscuits with an increase in the incorporation of PD &WPC. The highest value of fiber content was found in sample 5(5.78%), while the lowest value was found in the control sample (3.81%). A slightly similar study for fiber content is also presented in [1]. Crude fiber is responsible for promoting health benefits by binding to fat deposits in the digestive tracts of humans, preventing several degenerative diseases such as hypertension, diabetes and obesity[29].

3.21 Total carbohydrate

The amount of carbohydrate content in the developed biscuits was very negligible, ranged as 60.137-61.038% (Table 3). Aggarwal *et al.* [1] reported that the total carbohydrate content of control and optimized biscuits was in the range of 56.8-63.32%, respectively. Total carbohydrate content was highest (61.038%) in the case of sample 3, while sample 5 gave the lowest carbohydrate content (60.137%).

Table 3: Proximate analysis of fat replaced biscuits

Sample	Moisture	Protein	Fat	Ash	Fiber	Carbohydrates	Energy
Control	3.270±0.04	7.569±0.05	22.757±0.06	1.31±0.03	3.811±0.04	60.820±0.06	478.369±0.02
Sample 1	2.430±0.05	8.958±0.09	22.105±0.04	1.25±0.03	4.291±0.05	60.977±0.07	476.165±0.02
Sample 2	2.960±0.02	10.134±0.07	20.665±0.04	0.84±0.04	4.665±0.03	60.736±0.05	469.465±0.01
Sample 3	3.620±0.06	11.334±0.05	18.658±0.05	0.9±0.02	5.050±0.03	61.038±0.03	457.41±0.03
Sample 4	3.950±0.04	12.471±0.05	16.570±0.03	1.25±0.02	5.408±0.05	60.351±0.04	440.418±0.01
Sample 5	4.200±0.03	13.648±0.07	14.560±0.06	1.67±0.03	5.784±0.04	60.137±0.04	426.18±0.02

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3.22 Energy (Calorie)

Table 3 shows the amount of energy found from the consumption of 100 g biscuits. The amount of protein, carbohydrate, and fat content of the developed and stored biscuits affects the total energy content. The reduction of fat and sugar in the initial recipe by replacing with PD and WPC is responsible for the considerable lowering of the total calorie content. The control sample had the highest amount of energy as 478.369 cal/100 g biscuit, while sample 5 attributed with a minimum energy content of 426.18cal/100 g. It indicates that the best formulation is sample 5 as low-calorie biscuits, and it resulted in lowering approximately 10.9% calorie value. The amount of energy value of the optimized low-fat biscuit with the usage of sugar substitutes and dairy product fat replacers was recorded by [1] as 485.6 cal/100 g biscuit, which was around 7.59% lower than the energy value of their processed control biscuits. However, the total energy content of this study was in conformity with the energy values reported by [26] as 479.16 – 418.84cal/100 g.

3.3 Sensory Property Evaluation

The control obtained the highest color score (8.41), and the lowest score was obtained for sample 1 (7.53). In the case of taste, the Control biscuit sample showed the highest score (8.52), while sample 5 showed the lowest score (7.23). The taste of the biscuit decreased with the decrease in fat and sugar. But at the same time, the substitution of polydextrose and WPC in increasing amounts further improves the flavor of the biscuits. Texture and Appearance are the important quality feature of biscuit, which directly affects their acceptance and sales. The control sample (8.15) showed a high appearance score, and the lowest score showed sample 5 (6.64). The sensory score for appearance was found to be at decreasing level with an increasing level of WPC. Development of roughness on the surface of biscuits with increasing level of whey protein concentrate was the cause of poor appearance [18], but in some samples, due to polydextrose shiny appearance was also observed. In terms of texture score, the control sample had the highest score (8.10), and sample 5 had the lowest score (7.41). The texture is directly related to the composition of biscuits. Reduction in fat and sugar leads to the hardness in the biscuit, which gives the texture scores in decreasing pattern; however, all the scores are slightly different from the control sample. The overall acceptability was observed, and sample 4 was found to be with the highest acceptability score(8.36) than the control sample(8.20). The lowest score was obtained by sample 5(7.82). This sensory evaluation suggested that though the low–calorie biscuit is the sample 5 but has a high hardness value after baking and comprises poor sensory scores. Whereas sample 4 is next to the most low-calorie biscuit with a sensory score similar to control and the highest overall acceptability. Based on sensory properties, Sample 4, having PD & WPC (each 10gm), was used to partially replace the fat up to 40%. Sensory evaluation and selection can also be represented by the graph. However, all the biscuit samples scored higher than 6 and have slightly different values from the control biscuit. A similar type of result was found in [26]. Aggarwal *et al.*. [1] also noticed that the sensory values are higher for control biscuits than for the optimized biscuit.

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Table 4: Sensory analysis of fat replaced biscuits

Sample	Sensory attributes				
	Colour	**Taste**	**Appearance**	**Texture**	**Overall acceptability**
Control	8.41±0.51	8.52±0.38	8.15±0.45	8.10±0.44	8.20±0.41
Sample 1	7.53±0.56	8.02±0.42	7.41±0.43	8.11±0.52	7.86±0.45
Sample 2	8.01±0.62	8.12±0.67	7.65±0.49	8.21±0.61	8.50±0.65
Sample 3	8.16±0.49	8.06±0.49	7.46±0.62	7.94±0.48	8.14±0.57
Sample 4	8.23±0.53	8.32±0.72	7.92±0.52	7.87±0.64	8.36±0.43
Sample 5	7.86±0.65	7.23±0.51	6.64±0.54	7.41±0.55	7.82±0.68

Values are expressed as mean ± standard deviation of triplicate testing. Sample means values differ significantly at a 5%level of significance ($p<0.05$)

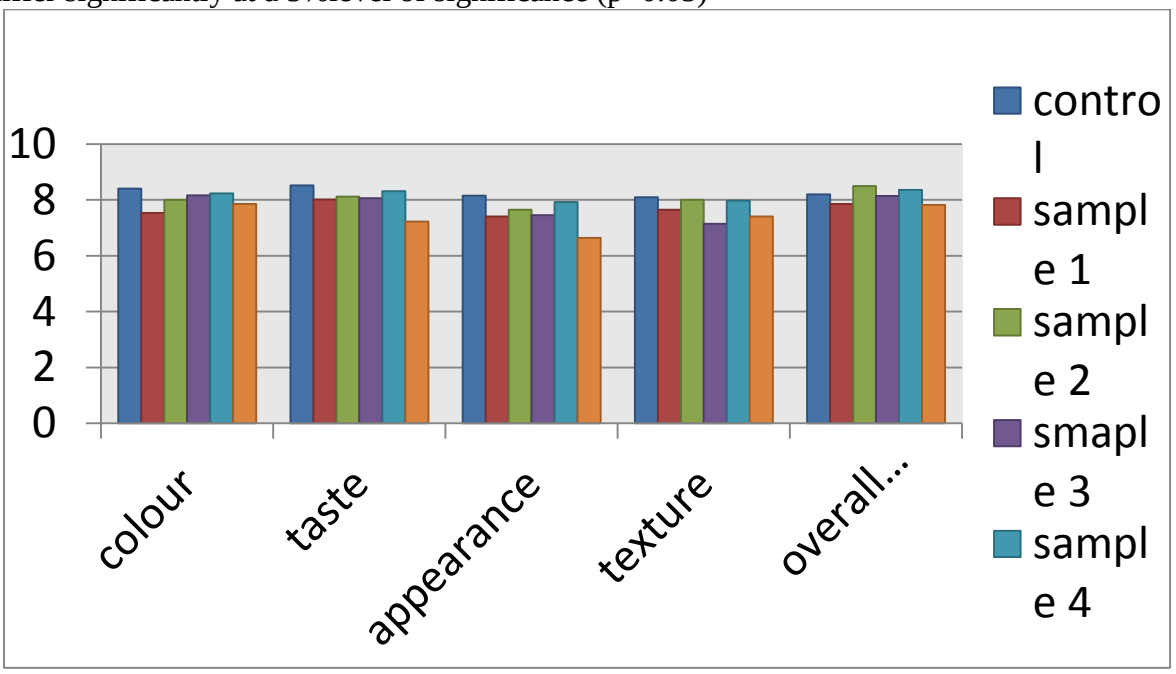

Fig. 2 Graphical representation of different attributes sensory score for control and samples

4. CONCLUSION

It can be concluded from this study that the Fat Replacers – polydextrose and whey protein concentrate incorporated in the multigrain flour blend (RWF + BF + CF:: 40+35+25g) and can be used successfully to partially replace the fat content by 40% for the formulation of the healthy multigrain low-calorie biscuits. Sample 4 of processed biscuits was considered an optimized biscuit as it was low fat, reduced the fat by 27.18% than control, and showed a higher overall acceptability score among the different biscuit samples. It is also considered equally in terms of sensory property and similar to physical property. The nutrition constituents like fiber, protein, and ash were higher than that of the control biscuits. However, Sample 5 also showed better physical and physiochemical quality than Sample 4, but it was hard to eat and chew and had a lower sensory score than Sample 4. The optimized biscuit

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sample had lower energy content 10.9% than the control product. The above study suggests that PD & WPC can be used as partial or complete fat replacers in biscuit-like products, and acceptably reduced-calorie products with the nutrition of multigrain flour can be prepared. However, further research is recommended in this domain, specifically on using and optimizing PD and WPC as fat replacers for maximally replacing fat and enhancing textural properties.

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