



Physico-Chemical Properties of Biscuits Enriched with Dried Microwave-Blanched Fruit Peelings

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Authors' contributions

This work was carried out in collaboration among all authors. Author FDR designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors FDR and AR managed the analyses of the study. Authors PAE, TB and MCM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To investigate the dough rheological properties as well as physical, nutritional, antioxidant and sensory properties of biscuits supplemented with dried microwave-blanched orange, apple and pomegranate peels at various levels (0-10%, wheat flour substitution).

Methodology: Water absorption capacity and pasting properties of wheat flour blended with fruit peels were assessed using farinograph and micro viscoamylograph. Physico-chemical properties as well as antioxidant activities were measured using standard methods. The sensory analysis was performed by trained panelists.

Results: Water absorption capacity of the dough increased significantly with increasing levels of orange and apple peels while it decreased with pomegranate peels. However, peak, hot paste, cold paste and breakdown viscosities of the dough significantly decreased with increasing

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proportions of apple and orange peels while they increased with pomegranate peels. The breaking force and weight of the biscuits supplemented with pomegranate peels were the lowest. Supplementation of biscuits with fruit peelings enhanced the ash and fibre content of the biscuits but had no significant effect on their antioxidant activities except for biscuits containing 10% apple peels which had higher antioxidant activity compared to biscuit controls. Biscuits supplemented with 5% of fruit peels were the most appreciated in terms of surface character, crumb colour and texture.

Conclusion: This study showed that dried microwave-blanching apple peels can be incorporated into biscuits to enhance both their nutritional and antioxidant properties.

Keywords: Biscuits supplemented with fruit peelings; dough rheology; physico-chemical properties; antioxidant activities; sensory properties.

1. INTRODUCTION

Biscuits are among the popular cereal based baked foods that are consumed at breakfast and as snack [1]. Previously, it was considered as a luxury consumption material, now it became a food which can be consumed by everybody. Biscuit producers now are diversifying their production for meeting the demands of consumers who are nowadays most attracted by healthy food products [2]. The development of functional foods is a unique opportunity to improve food quality and health of the consumer [3]. In this line, varieties of health promoting biscuits have been developed [1]. Their making process requires sometimes the incorporation of synthetic or natural bioactive compounds into biscuits. However, the use of natural sources of bioactive compounds is most preferred by the population for safety reasons mainly [4].

Fruit peelings, are food industry wastes which were used essentially for livestock feed and fuel purposes. The idea of utilizing fruit peelings in food industry have slowly gained popularity especially when researchers found that peels possessed better biological activities than other parts of the fruit [5]. Fruit peelings are good sources of fibres, minerals and phenolic compounds with antinutrient levels (phytates, oxalates, alkaloids) under the safety limits [6, 7]. Total phenolics content have been positively associated with antioxidant properties which play a positive role in the alleviation of oxidative stress and the prevention of free-radical mediated diseases [8].

An essential step in the optimization of the use of fruit peelings in food applications is to get rid of their moisture content and this is mostly achieved through dehydration. Water removal increases the shelf life and facilitates the use of fruit peelings in food products [9]. However, the temperature used during dehydration has

shown to have a negative effect on the fibre content and composition [10]. As functional properties depend on the chemical structure of the plant polysaccharides and protein [11], this potentially may modify the functional and technological properties of fruit peelings which are high fibre food matrixes. On the other hand, most of the drying methods lead to the corruption and degradation of carotenoids and flavonoids, anti-oxidant pigments responsible for the peel colour and to non-enzymatic browning reactions [12]. This affects the antioxidant potential and the organoleptic properties of dried fruit peelings and minimizes the benefits obtained from the biscuits supplemented with such treated peels. In fact, antioxidants are widely known for their heat labile properties suggesting potential losses in their bioactivity and associated health promotion properties upon the application of heat treatments [13]. Moreover, supplementing flour for making biscuits raises concerns with regard to consumer's acceptability for colour, taste, texture and other baking characteristics [14].

Feumba et al. [15] reported that microwave blanching for 3 to 5 min prior to drying preserve the antioxidant activity and reduce the browning rate of mango, apple, orange and banana peels. Although the enhancement of biological and organoleptic properties, these two processes consecutively applied may have a cumulative negative effect on the functional properties of fruit peelings and on their biscuit making potential. As Abou-Arab et al. [12] reported that microwave, solar and air oven drying applied individually affected significantly the functional properties of oranges, tangerine and lemon peels. In the same line, Garau, et al. [16] reported that the structural and compositional modifications which might occur during the pretreatment and drying process can influence the final quality of the dried by-products.

As of now, most reports on the biscuits supplemented with fruit peelings are mainly on peels subjected to only one treatment [17-19]. The objective of the present study was to investigate the effect of dried microwave-blanched peels of some selected fruits on the rheological properties of the dough as well as the physico-chemical characteristics, the antioxidant activity and the sensory properties of the resulting biscuits.

2. MATERIAL AND METHODS

2.1 Preparation of Fruit Peelings Powder

Ten kilograms of fresh and fully ripe fruits (orange, apple and pomegranate) were purchased from the Mysore District CFTRI Shop. The fruits used were orange Navel (*Citrus sinensis*), apple Red Delicious (*Malus sylvestris*) and red pomegranate (*Punica granatum* L.)

Fresh fruits were washed and allowed to dry at room temperature. For apple, the whole peel was removed, whereas for pomegranate and orange, only the colored part of the peel named pericarp or flavedo was removed using a sharpened knife. Fruit peelings were subjected to 3 min of microwave blanching prior to drying for 24h at 50 °C. The dried peels were grinded into fine flour and sieved at 200 µm.

2.2 Evaluation of Rheological Properties of Dough Blended with Fruit Peelings

The effect of replacement of wheat flour with 5 and 10 % orange, apple and pomegranate peels powder on farinograph and micro viscoamylograph characteristics were studied using standard AACC methods [20].

2.3 Preparation of Biscuits

Biscuits were processed by substituting wheat flour with fruit peelings powder (orange peels, pomegranate peels and apple peels) at level of 0, 5 and 10%. Then the biscuits were prepared using the formula described by Anuradha et al. [21]. After baking, biscuits were left to cool at room temperature and were wrapped tightly with polypropylene pouches and kept until further analysis. The biscuits with 0% of fruit peelings served as control.

2.4 Evaluation of Physical Characteristics of Biscuits

The method described by Bala et al. [22]. was used to evaluate the physical properties of biscuits. The thickness of biscuits was determined by stacking five biscuits samples, measuring the height with a digital vernier caliper and calculating the average value. The diameter of biscuits was obtained by measuring the diameter of five biscuit samples placed edge to edge; then the average value was considered. The spread ratio was calculated by dividing the diameter by thickness.

The weight of biscuits was measured as average values of five individual biscuits with the help of an analytical weighing balance. While the breaking force was evaluated using a texture analyser (TA-HDi texture Stable Microsystem and Surrey, UK) equipped with three points bending.

2.5 Determination of Proximate Composition of Biscuits

Moisture content was determined after oven drying to a constant weight at 105 °C. Ash, proteins, lipids and crude fibres were analysed according to AOAC methods [23, 24] and carbohydrates content was determined according to difference method.

2.6 Evaluation of Total Phenolics Content and Antioxidant Activities of Biscuits

The total phenolics content, ferric reducing antioxidant power and total antioxidant capacity of biscuits were assessed in the biscuits as described by Feumba et al. [15].

2.7 Statistical Analysis

All the measurements analyses were carried out at least in triplicate. The results obtained were expressed as mean ± standard deviation using Excell 2007 and the comparison between the variables was done using the multiple range test of DUNCAN through Statgraphics Plus 5.0 software. Statistical significance was defined at P < 0.05.

2.8 Sensory Evaluation of Biscuits

A trained panel of eight person aged 20 to 30 years was used to describe the biscuits. All

panellists work at Central Food Technological Research Institute and have a wide experience in sensory evaluation of baked products. In each questionnaire, the panellists were asked to evaluate the intensity of the following attributes of biscuits: colour, surface character, crumb colour, texture, mouth feel and overall quality. Water was provided to consumers for palate cleansing between samples.

3. RESULTS AND DISCUSSION

3.1 Rheological Characteristics of Wheat Flour Mixed with Fruit Peelings

3.1.1 Farinograph characteristics of wheat flour mixed with fruit peelings

Rheological characteristics of composite flours like water absorption, dough stability, dough development time were computed by using Farinograph (C.W. Brabender). The farinograph characteristics of the dough were as recorded in Table 1.

It is observable that water absorption of wheat flour primarily of 54.4% increased gradually up to 62% and up to 56.4% with increasing concentrations from 5 to 10% of orange and apple peels respectively. Sudhakar and Maini [25] reported that the increase in water absorption was due to the interaction between water and hydroxyl groups of polysaccharides through hydrogen bonding. It's well known that the fruits peels contain dietary fibres including pectin, lignin, β -glucan, cellulose and hemi-cellulose; therefore, the interaction of water and hydroxyl groups of these compounds resulted in high water absorption [26]. However, differences in water absorption might be due to the greater number of hydroxyl groups which exist in the fibre structure and allow more water interaction through hydrogen bonding [27]. In the other hand, the water absorption of wheat flour decreased from 54.4 to 50.4% upon addition of pomegranate peels.

Controversially to wheat flours blended with pomegranate peels, wheat flours blended with orange and apple peels exhibited lowest dough development and dough stability compared to wheat flour. This behaviour may be probably due to their high lipids content compared to pomegranate peels. Feumba et al. [7] reported a lipids content of 8.70% for orange peels, 9.96 % for apple peels and 3.36% for

pomegranate peels. Ashoush and Gadallah [28] claimed decreased dough development time and dough stability of flour blended with mango kernels powders due to the high lipid content of mango kernels of 8.15%. Ajila et al. [29] also reported that a decrease in dough stability indicated the decrease in dough strength which may be due to the dilution of gluten proteins in wheat flour upon addition of mango peel and kernel powders.

The poor dough stability observed after supplementation of orange and apple peels to wheat flour was reflected in significantly higher mixing tolerance index. The tolerance index increased possibly as a result of decreased elasticity of the dough as influenced by gluten dilution.

3.1.2 Pasting characteristics of wheat flour mixed with fruit peelings

The pasting characteristics evaluated using a micro viscoamylograph were displayed in Table 2. Supplementing wheat flour with 5 or 10% of orange, pomegranate and apple peels had no significant influence on gelatinization temperature. Peak, hot paste, cold paste and breakdown viscosities significantly decreased with increasing proportions of apple and orange peels. But when pomegranate peel is incorporated in wheat flour, these viscosities increased.

Saartrat et al. [30] reported that variations in peak viscosity were related to the chemical compositions of the samples. In canna starches where phosphate and calcium group are high, phosphate group and calcium are supposed to form bonding and therefore canna starches could behave like a cross-linked starch resulting in a decrease in peak viscosity [30]. Pomegranate peels have calcium groups and more than twentyfold the levels of oxalates in apple and orange peels [7]. Oxalates can bind to calcium [31] forming crystals of calcium oxalates which can affect the behaviour of the blend by increasing peak viscosity and breakdown.

In the other hand, Table 2 reveals the value of the setback is higher with incorporation of 5% compared to 10% peel indicating that blends containing 10% peels have less tendency to retrogradation compared to blend with 5% peels. The decrease in the value of the setback may be

Table 1. Effect of fruit peelings on farinograph characteristics of wheat flour

Sample	Water absorption (%)	Development time (min)	Stability(min)	Tolerance index (FU)	Time to breakdown(min)
WF	54.4 ± 0.2 ^a	5.3 ± 0.1 ^a	5.7 ± 0.1 ^a	61 ± 2 ^a	7.2 ± 0.2 ^a
WF with OP 5%	57.9 ± 0.3 ^b	4.8 ± 0.2 ^b	3.9 ± 0.3 ^b	70 ± 2 ^b	6.4 ± 0.4 ^b
WF with OP 10%	62.0 ± 0.4 ^c	4.0 ± 0.4 ^c	2.0 ± 0.2 ^c	86 ± 4 ^c	5.1 ± 0.4 ^c
WF with PP 5%	53.6 ± 0.2 ^d	9.7 ± 0.1 ^d	18.8 ± 0.3 ^d	12 ± 2 ^d	20.0 ± 0.2 ^d
WF with PP 10%	50.4 ± 0.4 ^e	2.7 ± 0.2 ^e	18.9 ± 0.2 ^d	44 ± 4 ^e	3.3 ± 0.2 ^e
WF with AP 5%	54.8 ± 0.2 ^a	3.8 ± 0.2 ^f	4.5 ± 0.4 ^e	67 ± 2 ^b	6.4 ± 0.2 ^b
WF with AP 10%	56.4 ± 0.4 ^f	4.2 ± 0.2 ^c	5.1 ± 0.3 ^f	58 ± 4 ^a	7.0 ± 0.4 ^a

WF: Wheat flour; OP: Orange peels; PP: Pomegranate peels; AP: Apple peels Values are mean ± standard deviation; n = 3 Means in the same column with different superscript letters are significantly different (P < 0.05)

Table 2. Pasting characteristics of blends made with wheat flour and fruit peelings

Sample	Gelatinization temperature (°C)	Peak viscosity (BU)	Hot Paste viscosity (BU)	Cold Paste viscosity (BU)	Breakdown (BU)	Setback (BU)
Wheat flour (WF)	60.4 ± 0.1a	826 ± 3a	552 ± 3a	941 ± 3a	274 ± 6a	389 ± 3a
WF with OP 5%	60.2 ± 0.1a	784 ± 3b	527 ± 2b	922 ± 2b	257 ± 4b	395 ± 3a
WF with OP 10%	60.8 ± 0.1a	683 ± 2c	435 ± 2c	760 ± 2c	248 ± 2c	325 ± 2b
WF with PP 5%	59.9 ± 0.1a	863 ± 3d	574 ± 3d	1020 ± 2d	289 ± 3d	446 ± 3c
WF with PP 10%	59.9 ± 0.1a	853 ± 2e	563 ± 2e	974 ± 3e	290 ± 2d	411 ± 2d
WF with AP 5%	60.4 ± 0.1a	789 ± 2b	528 ± 2b	942 ± 2a	261 ± 2b	414 ± 2d
WF with AP 10%	60.7 ± 0.1a	700 ± 2f	463 ± 2f	820 ± 3f	237 ± 2f	357 ± 3e

WF: Wheat flour; OP: Orange peels; PP: Pomegranate peels; AP: Apple peels Values are mean ± standard deviation; n = 3 Means in the same column with different superscript letters are significantly different (P < 0.05)

explained by increasing proportion of lipids in the blend due to appreciable lipid content of the peels. Singh et al. [32] attributed the low tendency to retrogradation of corn flour to its high lipid content which may form a complex with amylose.

3.2 Physico-Chemical Characteristics of Biscuits Supplemented with Fruit Peelings

3.2.1 Physical characteristics of biscuits supplemented with fruit peelings

The physical characteristics of biscuit depend upon the composition of matrix. The physical characteristics of biscuits supplemented with fruit peelings were presented in Table 3. From there, it was noticeable that the thickness, diameter and breaking force of biscuits supplemented with fruit peelings were similar to those of biscuit control except for biscuits made of 10% pomegranate where those values are low compared to the control biscuit. Aslam et al. [33] reported that changes in the width and in the thickness of biscuit are related to gluten. So, the incorporation of pomegranate peel into biscuit formulation at a percentage of 10 affected gluten formation and therefore influence the thickness, diameter and breaking force or hardness of biscuits. The hardness of biscuit is a result of development of gluten network. Gluten promotes the network development by attracting the water molecules [34]. In the other hand, the decreasing weight observed with increasing percentage of peels into the biscuits might be due to the high fibre content of peels.

3.2.2 Nutritional composition of biscuits supplemented with fruit peelings

The nutritional composition of biscuits supplemented with fruit peelings was displayed in Table 4. Increased proportions of fruit peelings in the biscuits resulted in a gradual (except for pomegranate peels) and significant decrease of their protein content. Reduction in protein contents has been also reported by Ismail et al. [18] after incorporation of pomegranate peels into cookies. However, lipid content of the biscuits was significantly increased after incorporation of fruit peelings except for pomegranate peels. This may probably due to the high content of orange and apple peels compared to pomegranate peels. Similar increase was observed by Youssef

and Mousa [35]. after incorporation of 10% orange peels to biscuits. The caloric value of the biscuits was not significantly ($p < 0.05$) affected by replacement of wheat flour by fruit peelings. On the contrary biscuits supplemented with 10% pomegranate peels were less caloric than the others. Those findings were consistent with Ismail et al. (2014) and Youssef and Mousa [18, 35] who respectively observed a decrease of caloric value of biscuits supplemented with pomegranate and an increase of caloric value of biscuits fortified with orange peels. These diverse effects of fruit peelings on caloric value of biscuits might be due to their difference in lipid or protein content which are contributors to caloric value of food products. However, ash and fibre contents of the biscuits were significantly enhanced by the replacement of wheat flour by fruit peelings.

3.3 Antioxidant Activities of Biscuits Supplemented with Fruit Peelings

From Table 5, it was noticeable that incorporation of orange, pomegranate and apple peels in biscuits formulation had no significant effect on the phenolic contents of biscuits although our previous work demonstrated that these fruit peelings had high total phenolics content [15]. An explanation might be the destruction of these phenolics as some of them are thermolabile [36] or their involvement in other reactions. The Maillard precursors [37] or Maillard intermediates [38] formed during baking have the potential of complexing the phenolic compounds thus leading to a decreased level in the phenolic contents but to an increase in antioxidant activities of the supplemented biscuits.

In the same line, replacing wheat flour by fruit peelings had no significant effect on the ferric reducing antioxidant power and total antioxidant activity of biscuits except in biscuits supplemented with 10% of apple peels which had higher antioxidant activity compared to biscuit controls. This observation was contrary to that found by Ismail et al. [18] who reported a dose-dependent response in antioxidant activity of cookies supplemented with pomegranate peels.

3.4 Sensory Analysis of Biscuits Supplemented with Fruits Peelings

The biscuits prepared using wheat flour supplemented with different level of fruits peelings were subjected to sensory evaluation

Table 3. Physical characteristics of biscuits supplemented with fruit peelings

Biscuits sample	Thickness (cm)	Diameter (cm)	Spread ratio	Breaking force (N)	Weight (g)
Biscuit control	0.51 ± 0.01 ^a	5.66 ± 0.10 ^a	11.31 ± 0.19 ^a	11.27 ± 0.87 ^a	6.77 ± 0.01 ^a
Biscuit with OP 5%	0.53 ± 0.01 ^a	5.63 ± 0.07 ^a	10.71 ± 0.16 ^b	10.39 ± 1.29 ^a	6.63 ± 0.01 ^b
Biscuit with OP 10%	0.51 ± 0.01 ^a	5.63 ± 0.05 ^a	11.12 ± 0.29 ^{ab}	10.61 ± 1.62 ^a	6.59 ± 0.01 ^c
Biscuit with PP 5%	0.53 ± 0.01 ^a	5.67 ± 0.04 ^a	10.80 ± 0.07 ^b	9.29 ± 1.27 ^{ab}	6.26 ± 0.01 ^d
Biscuit with PP 10%	0.48 ± 0.01 ^b	5.56 ± 0.03 ^b	11.71 ± 0.07 ^c	7.86 ± 1.01 ^b	6.16 ± 0.01 ^e
Biscuit with AP 5%	0.53 ± 0.01 ^a	5.64 ± 0.10 ^a	10.74 ± 0.18 ^{cd}	10.73 ± 2.17 ^a	6.93 ± 0.01 ^f
Biscuit with AP 10%	0.53 ± 0.01 ^a	5.68 ± 0.05 ^a	10.81 ± 0.10 ^d	13.18 ± 1.14 ^a	6.87 ± 0.01 ^g

OP: Orange peels; PP: Pomegranate peels; AP: Apple peels Values are mean ± standard deviation; n = 5 Means in the same column with different superscript letters are significantly different (P < 0.05)

Table 4. Proximate composition of biscuits supplemented with fruit peelings

Sample	Protein (%)	Lipid (%)	Ash (%)	Crude fibre	Carbo hydrate	Caloric value (Kcal/100g)
Biscuit control	8.40±0.16a	15.54±0.28a	1.42±0.01a	0.17±0.05a	74.47±0.23a	470.74±0.3
Biscuit with OP 5%	7.82±0.23b	15.04±0.24a	1.31±0.35ad	0.99±0.02b	74.84±0.24a	466.00±0.1
Biscuit with OP 10%	7.25±0.01c	17.00±0.02b	2.23±0.82ad	1.00±0.03b	72.52±0.36a	472.08±0.5
Biscuit with PP 5%	7.95±0.21b	15.96±0.17a	1.37±0.21ad	1.50±0.05c	73.22±0.14a	468.32±0.9
Biscuit with PP 10%	7.53±0.25b	15.27±0.69a	1.88±0.33d	2.94±0.03d	72.38±0.28a	457.07±1.5
Biscuit with AP 5%	7.77±0.11b	15.21±0.02a	1.44±0.03a	0.38±0.05e	75.20±0.84a	468.77±0.7
Biscuit with AP	7.46 ±0.06d	16.73±0.28b	1.91±0.21d	0.68±0.03f	73.22±0.16a	473.29±0.2

OP: Orange peels; PP: Pomegranate peels; AP: Apple peels Values are mean ± standard deviation; n = 3 Means in the same column with different superscript letters are significantly different (P < 0.05)

Table 5. Total phenolics content of biscuits and antioxidant activities of biscuits supplemented with fruit peelings

Sample	Total Phenolics Content (g GAE/100g)	Antioxidant Activity	
		Reducing Power(mg AAE/100g)	Total Antioxidant Activity (mg BHA/E/100g)
Biscuit control	0.49 ± 0.05a	0.85 ± 0.03a	0.85 ± 0.03a
Biscuit with OP 5%	0.31 ± 0.03b	0.54 ± 0.02b	0.74 ± 0.01b
Biscuit with OP 10%	0.46 ± 0.08a	0.80 ± 0.01a	0.92 ± 0.07ac
Biscuit with PP 5%	0.47 ± 0.01a	0.64 ± 0.02c	0.87 ± 0.01a
Biscuit with PP 10%	0.40 ± 0.02a	0.55 ± 0.03b	0.88 ± 0.02a
Biscuit with AP 5%	0.39 ± 0.01a	0.66 ± 0.01c	0.89 ± 0.04a
Biscuit with AP 10%	0.39 ± 0.05a	1.16 ± 0.01d	1.00 ± 0.05c

OP: Orange peels; PP: Pomegranate peels; AP: Apple peels Values are mean ± standard deviation; n = 3 Means in the same column with different superscript letters are significantly different (P < 0.05)

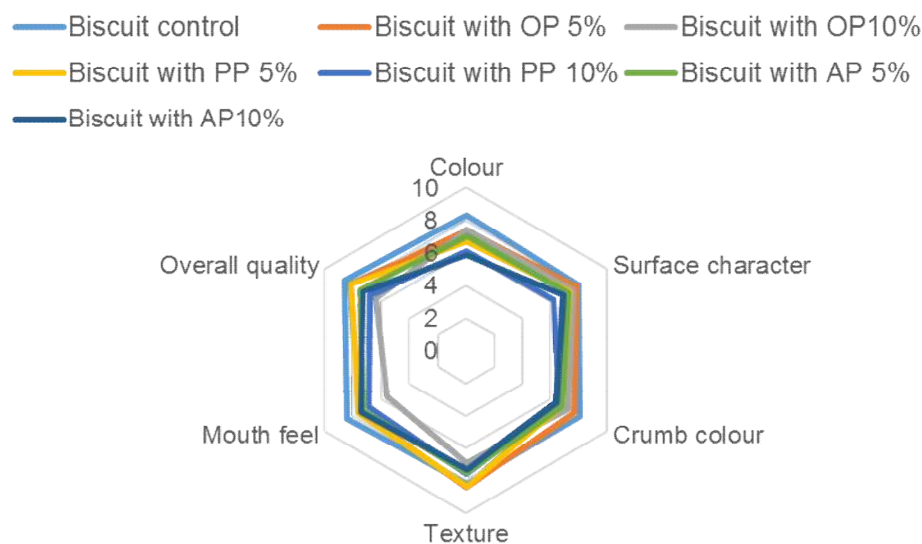


Fig. 1. Sensory analysis of biscuits supplemented with fruits peelings

and the scores were recorded in Fig. 1. The results showed that biscuit control had the highest score in all the sensory parameters studied. Generally, the appreciation of colour decreased with incorporation of fruits peels. A similar trend was observed by Ismail et al. [18] reporting a significant reduction in colour score with increasing incorporation of pomegranate peel into cookies. Biscuits supplemented with 10% orange peels have exhibited lowest score for mouth feel and overall quality due to the bitter taste perceived by the panellists. Bom et al. [39] suggested the addition of bitter taste blockers to improve the acceptability and consumption levels of astringent functional foods. However, the texture of biscuits supplemented with 5% pomegranate peels was the most appreciated and scores obtained for surface character and crumb colour of biscuits supplemented with 5% fruits peels were comparable to those of biscuit controls.

4. CONCLUSION

The study concludes that it is possible to prepare biscuits by incorporation of microwave-blanching prior to drying fruit peelings. The addition of fruit peelings influenced the rheological properties of the biscuit dough and the physical characteristics of resulting biscuits, depending on the level and

the nature of fruit peelings (orange, apple, pomegranate) used. Ash and fibre were the nutritional parameters enhanced by the incorporation of fruit peelings. Meanwhile, no significant change was observed in the phenolic content and antioxidant activities of the biscuits except for biscuits containing 10% apple peels. It was found that biscuits prepared by substitution of 5% were most acceptable in terms of surface character, crumb colour and texture. This study showed that dried microwave-blanching apple peels can be incorporated into biscuits to enhance both their nutritional and antioxidant properties.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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