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ORIGINAL ARTICLE

Valorization of microwave roasted *Tamarindus indica* seed in functional biscuit production and effects on rheological and textural properties of biscuit dough

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Abstract As one of the most popular bakery products, biscuits lack several nutrients such as fiber, protein, and some minerals. In this study, biscuits were enriched with *T. indica* seed flour. *T. indica* seeds were roasted by microwave at 600 W for 8, 16 and 24 min. Wheat flour was substituted by unroasted and roasted tamarind flour at level of 10%. Owing to its appreciated antioxidant activity, fiber and protein content, *T. indica* seed flour improved the nutritional value and antioxidative properties of biscuits. The fiber content of biscuits increased up to $3.88 \pm 0.02\%$ and protein content up to 11.22 ± 0.05 ($p < 0.05$). Moderately roasting process developed the sensory and antioxidative properties of *T. indica* seeds. Microwave roasting was used successfully for roasting *T. indica* seeds.

Keywords Biscuit · Fiber · Antioxidant · Protein

Introduction

Recently, food needs and preferences of consumers have changed considerably. Food industry has been trending toward the production of foods with a limited use of chemicals to obtain healthier and fibre-rich foods. Many enriched bakery products have been produced for this aim. Ivanišová et al. (2020) investigated effects of chicory fiber extract on biscuits. The fiber, crude protein, and ash content of biscuits increased with addition of chicory fiber extract. Apostol et al. (2017) enriched wheat flour using pumpkin powder. In the result of this study, pumpkin powder developed the nutritional value and mineral content of wheat flour. Bolek (2020) used olive stone powder to enrich biscuits. Olive stone increased antioxidant activity significantly ($p < 0.05$).

Tamarindus indica, commonly known as tamarind, is a leguminous tree indigenous to tropical Africa (Pino et al. 2004). It is one of the most important plant resources as food materials. The fruit is accepted as an herb medicine in some regions of the world (De Caluwé et al. 2010). It is showed high level of polyphenolic compounds (Tril et al. 2014). On the other hand, the seeds of tamarind have high antioxidant activity (Sudjaroen et al. 2005). Furthermore, the seeds are rich source of phenolic compounds (López-Hernández et al. 2018). Tamarind seeds are considerably high in fiber (Mahajani 2020). Apart from being a source of various nutrients, tamarind seeds impart excellent aroma to food. Roasting process develops the flavor of tamarind seeds (Bashir et al. 2016). On the other hand, Akajiaku et al. (2014) were found that roasting is effective in reducing various anti-nutritional components of tamarind seed without affecting the nutritional quality. However, they did not evaluate the effects of roasting on antioxidant activity and total phenolic content.

The Maillard reaction and caramelization are responsible for creating a majority of aroma and flavor compounds in roasted food materials (Mottram 2007). The reactions produce a lot of nutty, caramelly, chocolatey, malty flavors. Roasting process also leads to improvement of color and textural properties of food materials (Goszkiewicz et al. 2020). Roaster type and roasting temperature are critical factors to be considered for development of desired aroma and flavor profile. Conventional roasting is commonly used for roasting of many food items including coffee beans and nuts. However, characterizing by long temperature

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and long time roasting, the conventional roasting methods may develop certain undesirable flavor characteristics such as harsh, phenolic, smokey and tarry flavor notes, and an unpleasant acidity (Bagheri 2020). In these techniques, the exterior surfaces of the food materials are over roasted, when the center of the food materials is not homogenously roasted. This causes non-uniform roasting, bitter burned taste, burned surfaces and, development of unpleasant aroma and flavor (Bolek and Ozdemir 2017). Moreover, traditional roasting tecniques are time-consuming with high energy consumption and low production efficiency. However, microwave roasting helps in roasting foods without burning. One of the greatest advantages of the microwave oven is time-saving. Microwaves are also very economical and consume much less energy than both gas burners and conventional oven.

Thanks to their cheapness, long shelf life and ready to eat nature, biscuits are one of the most favorable snack foods among all age groups. However, biscuits lack several nutrients such as fiber, protein, and some minerals. Owing to its appreciated antioxidant activity, fiber and protein contents, tamarind seed flour can improve the nutritional value and antioxidative properties of biscuits. In the United States, Tamarindus indica seed products are marketed with Generally Recognized As Safe (GRAS) status, granted by the US Food and Drug Administration (FDA) in 2014. However, only a few studies have been performed regarding the using tamarind seed in bakery products (Chakraborty et al. 2016; Natukunda et al. 2016). In addition, these studies were not investigated the effects of roasted tamarind seed. Moreover, microwave roasting, which is a quick and practical method, has not been used for this aim. On the other hand, effects of tamarind seed on rheological and textural properties have not been determined so far. Therefore, in this study it was aimed to enrich biscuit with microwave roasted *T. indica* seed flour as a nutritional snack with desired aroma and flavor characteristics.

Material and methods

Materials

Type 500 soft wheat flour, white sugar, butter, ammonium bicarbonate. sodium chloride, sodium bicarbonate, lecithin, salt, and skim milk powder were purchased from a commercial market in Üsküdar, İstanbul.

The *T. indica* was obtained from an herbalist in Eminönü, İstanbul, Turkey and preserved at − 18 °C.

Preparation of *T. indica* flour

The seeds were extracted manually from mature pods of *T. indica.* The seeds were rinsed with distilled water to remove any adhering flesh. Then they were roasted in a microwave oven (Siemens, HF12G540) at 600 W for 8, 16, 24 min. Roasting times were determined by preliminary experiments to obtain light roasted, medium roasted and dark roasted tamarind seeds. The roasted seeds were ground by a grinder (Pulverisette 14, Fritsch, Germany), which is equipped with a sieve system, with a particle size of 150 μm.

Biscuit production

Biscuit samples were prepared according to the AACC Method No. 10–54 (AACC 2000), using a mixer. Biscuit dough was prepared with wheat flour (100 g), skimmed milk powder (2.0 g), sugar (30 g), butter (10 g), lecithin (1.0 g), ammonium bicarbonate (1.0 g), salt (0.3 g), sodium chloride (1 g), sodium bicarbonate (0.5 g), and deionized water (20 ml).

Wheat flour was substituted by roasted tamarind flour at level of 10%.

Rheological properties of biscuit dough

The dough characteristics were determined using farinograph (CW Brabender Instruments, Duisberg, Germany) based on the AACC approved methods (AACC 2000).

Extensibility of biscuit doughs were analyzed by SMS/Kieffer rig and Texture Analyser (Stable Micro Systems) according to the AACC approved methods (AACC 2000). The test was performed using the following parameters: pre-test speed: 2 mm/s; test speed: 2 mm/s; post test speed: 5 mm/s; data acquisition rate: 200 PPS. After 25-min resting the dough was placed in Kieffer rig and stretched.

The textural properties of biscuit dough were measured by Texture Analyser (Stable Micro System) using two-bite ‘texture profile analysis based on the method of Peleg (1976). The test was performed using the following parameters: cylinder probe diameter, 2.54 cm; load cell, 50 kg, pre-test speed: 1 mm/s, test speed: 2 mm/s.

Proximate analysis

Crude fiber, protein, fat, and ash contents of tamarind seeds and biscuit samples were determined according to the AOAC (2005). The moisture contents of tamarind seeds and biscuit samples were determined by an infrared moisture meter (Ohaus Moisture Balance 601C; Ohaus, NJ). Proximate analysis was done in triplicate.

Color measurements

The effects of the roasted tamarind seed flour on colors of biscuits were determined by a chroma meter (CR-400, Konica Minolta). Ten replications were done for each biscuit samples.

Antioxidant activity

The antioxidant capacity of *T. indica* seeds and biscuit samples were analyzed by using DPPH assay as following Wu et al. (2003) with slight modification. 0.0003 g of DPPH was dissolved in 50 ml ethanol. 1.5 mL diluted sample was mixed with 1.5 mL DPPH, vortexed and incubated for 30 min in the dark. Absorbance at 517 nm was determined with an UV–VIS spectrophotometer. The results were reported as Trolox equivalent.

Total phenolic content

The total phenolic content analysis was conformed that of Rossi and Singleton (1966) with slight modifications. Total phenolic content was measured according to the Folin-Ciocalteu method. Five mL of Folin-Ciocalteu solution and distilled water reagent (1:10) were mixed with 0.5 mL sample. The content was vortexed. Then it was incubated at 25 °C for 5 min. The solution was balanced with 4 mL of 1 M sodium carbonate solution. After incubation at dark, the absorbance of the extract was measured by an UV–VIS spectrophotometer.

Textural properties of biscuit samples

A texture profile analyzer (TA.XT plus Stable Micro Systems, England) was employed to measure textural properties of biscuit samples. 5 kg load cell and 36 mm cylinder probe were employed. The pre-test speed, test speed and post-speed were determined 0.1 mm/s, 0.2 mm/s, and 0.5 mm/s respectively. Ten replicates for each treatment were tested.

Sensory properties

Sensory properties of biscuits were tested by untrained 72 panelists (40 female 32 male). Five-point hedonic scale was used to evaluate appearance, odor, texture, flavor and overall impression of biscuit samples. The samples were evaluated in a test room designed according to norm ISO 8589 (2007). Randomized coded four biscuits were evaluated in an evaluation session.

Statistical analysis

SPSS software (version 20.0) was used for Analysis of variance (ANOVA) of the experimental data. To compare the means at the level of $p < 0.05$, Duncan's multiple range test was used. Data of the experiments were reported as mean ± SD.

Results and discussion

Effects of microwave roasting on proximate composition on tamarind seeds

Effects of microwave roasting on proximate composition on tamarind seeds are given in Table 1. As the roasting proceeded, the moisture content of tamarind seeds significantly reduced ($p < 0.05$). This may be due to the dehydration during roasting. The crude protein contents of tamarind seeds decreased significantly as the roasting proceeded. As the roasting time increased, the antioxidant activity and total phenolic contents of tamarind seeds significantly increased ($p < 0.05$). Priftis et al. (2015) explained this pneumonia for roasted coffee beans with the formation of new antioxidative compounds caused by Maillard reaction products which lost or undergo pyrolysis during the roasting process as the roasting progresses under more severe conditions.

Rheological properties of biscuit dough

Effects of unroasted and microwave roasted tamarind seed flour on rheological properties of biscuit dough are shown in Table 2. Tamarind seed increased the water absorption capacity of biscuit dough ($p<0.05$). This result could be attributed to the rich dietary fiber content of tamarind seeds (Mahajani 2020). As the roasting degree increased, the water absorption capacity decreased significantly ($p<0.05$). Jideani et al. (2009) reported that water absorption capacity of protein can be improved by partial denaturation. Thus, the decrease in water absorption capacity of roasted tamarind flour may be due to partial denaturation of proteins. Decreased dough stability may be caused by the disruption of the gluten networks (Nandeesh et al. 2011).

Tamarind seed flour increased the hardness, cohesiveness and adhesiveness values of dough significantly. However, roasted tamarind seed flour decreased these values significantly ($p<0.05$). Unroasted and roasted tamarind seed flour decreased extensograph values of biscuit dough. This decrease could be explained by the dilution of gluten proteins or interactions between polysaccharides and proteins from wheat flour (Mohammed et al. 2012).

Table 1 Proximate composition of unroasted and microwave roasted tamarind seeds

	Unroasted	Roasted (8 min)	Roasted (16 min)	Roasted (24 min)
Moisture (%)	7.96 ± 0.12^{a}	6.22 ± 0.02^{b}	4.62 ± 0.01^{c}	3.05 ± 0.03^{d}
Crude protein (%)	22.44 ± 0.25^{a}	20.53 ± 0.01^{b}	18.22 ± 0.04^{c}	16.22 ± 0.02^{d}
Crude fiber (%)	5.98 ± 0.32^{a}	5.58 ± 0.03^{a}	5.02 ± 0.03^{a}	4.50 ± 0.04^{a}
Fat (%)	6.62 ± 0.02^{a}	6.80 ± 0.02^{a}	6.92 ± 0.05^{a}	7.16 ± 0.04^{a}
Ash (%)	4.46 ± 0.14^{a}	4.32 ± 0.03^{a}	4.08 ± 0.02^{a}	3.56 ± 0.01^{a}
Antioxidant activity (inhibition %)	32.22 ± 0.52^{c}	35.36 ± 0.12^{b}	39.73 ± 0.02^{a}	40.48 ± 0.03^{a}
Total phenolic content (mg GAE/ 100 g)	990.22 ± 1.20^{c}	125.14 ± 0.13^{b}	136.48 ± 0.16^{a}	138.70 ± 0.12^{a}

Mean of three determination ± standard error. Means followed by the same letters in the same line do not differ at the level of 95% of probability

Table 2 Effects of tamarind seed flour on textural and rheological characteristics of biscuit dough

Treatments	Farinograph		Textural				Extensograph	
	Consistency (BU) (10 min)	Water absorption capacity (%)	Hardness (N)	Springiness (mm)	Cohesiveness	Adhesiveness (N.S)	Extensibility (mm)	Resistance to extensibility (g)
$T_{control}$	290^{b}	60^{e}	24.08^{b}	0.709^{b}	0.25^{b}	47.22^{a}	46.55^{a}	12.41^{a}
$T_{0\ min}$	294^{a}	63^{d}	26.22^{a}	0.654^{e}	0.27^{a}	42.18^{b}	43.22^{b}	9.24^{b}
$T_{8\ min}$	288^{c}	67^{c}	$23.36^{b,c}$	0.682^{d}	0.23^{c}	40.16^{c}	41.48^{c}	7.71^{c}
$T_{16\ min}$	284^{d}	71^{b}	21.22^{c}	0.699^{c}	0.21^{d}	38.32^{d}	37.63^{d}	6.24^{d}
$T_{24\ min}$	280^{e}	75^{a}	$20.16^{c,d}$	0.720^{a}	$0.20^{d,e}$	37.45^{e}	$35.36^{d,e}$	$5.82^{d,e}$

Mean of three determination ± standard error. Means followed by the same letters in the same line do not differ at the level of 95% of probability

Effects of tamarind flour on proximate composition on biscuit samples

Effects of unroasted and microwave roasted tamarind seed flour on proximate composition of biscuits are given in Table 3. Tamarind seed flour significantly increased the moisture contents of biscuits ($p < 0.05$). The increase in moisture content can be explained by the increased water absorption capacity of biscuits thanks to the high fiber content of tamarind seeds. Jan et al. (2018) investigated the effects of replacement of wheat flour with quinoa flour on cookies. They found similar results for moisture content of biscuits enriched with high fiber quinoa flour.

The total protein, ash and fiber contents of biscuits significantly increased with addition of *T. indica* seed flour ($p < 0.05$) thanks to the high protein, ash, and fiber content of *T. indica* seed flour. However, substitution of wheat flour with *T. indica* seed flour decreased the fat contents significantly ($p < 0.05$). This may be due to the relatively low-fat contents of tamarind flour.

Color measurements of biscuits

Color is a descriptive feature for consumer acceptance. Effects of *T. indica* flour on color values of biscuits are

Table 3 Effects of tamarind seed flour on proximate composition of biscuits

Rosting degree	Moisture Content (%)	Fat (%)	Total protein (%)	Ash (%)	Crude Fiber (%)
$T_{control}$	2.48 ± 0.04^{d}	20.70 ± 0.02^{a}	9.78 ± 0.05^{bc}	1.96 ± 0.03^{b}	0.91 ± 0.02^{b}
$T_{0\ min}$	3.52 ± 0.03^{a}	18.63 ± 0.12^{b}	11.22 ± 0.05^{a}	2.95 ± 0.04^{a}	3.88 ± 0.02^{a}
$T_{8\ min}$	3.20 ± 0.05^{b}	18.72 ± 0.10^{b}	10.18 ± 0.08^{b}	2.90 ± 0.05^{a}	3.32 ± 0.07^{a}
$T_{16\ min}$	3.02 ± 0.01^{c}	18.78 ± 0.18^{b}	9.01 ± 0.06^{c}	2.82 ± 0.05^{a}	3.08 ± 0.07^{a}
$T_{24\ min}$	2.62 ± 0.02^{de}	18.85 ± 0.22^{b}	8.05 ± 0.04^{d}	2.78 ± 0.07^{a}	3.02 ± 0.09^{a}

Mean of three determination ± standard error. Means followed by the same letters in the same line do not differ at the level of 95% of probability

Table 4 Effects of tamarind seed flour on color and texture values of biscuits

Roasting degree	L*	a*	b*	Hardness (N)	Fracturability (N)
$T_{control}$	67.14 ± 0.24[a]	11.82 ± 0.02[a]	33.91 ± 0.22[a]	28.62 ± 0.86[b]	24.36 ± 0.12[b]
$T_{0\ min}$	63.41 ± 0.13[b]	11.22 ± 0.05[a]	31.88 ± 0.18[b]	30.27 ± 0.78[a]	27.55 ± 0.36[a]
$T_{8\ min}$	55.20 ± 0.15[c]	13.18 ± 0.03[a]	28.32 ± 0.27[c]	25.52 ± 0.65[c]	22.57 ± 0.23[c]
$T_{16\ min}$	49.02 ± 0.21[d]	14.01 ± 0.02[a]	23.08 ± 0.33[d]	22.83 ± 0.36[d]	20.26 ± 0.32[d]
$T_{24\ min}$	42.62 ± 0.12[e]	15.05 ± 0.04[a]	18.48 ± 0.19[e]	20.12 ± 0.44[e]	18.36 ± 0.86[e]

Mean of ten determination ± standard error. Means followed by the same letters in the same line do not differ at the level of 95% of probability

shown in Table 4. Addition of *T. indica* seed flour to the biscuit formulation affected the L*, a*, b* values significantly ($p < 0.05$). The L* and b* values of biscuit samples enriched with *T. indica* seed flour were significantly lower than the control biscuits ($p < 0.05$). Moreover, as the roasting degree of *T. indica* seeds increased, L* and b* values decreased significantly. This result could be explained by non-enzymatic browning reactions such as Maillard and caramelization occurred during roasting. Jogihalli et al. (2017) used microwave for roasting chickpea and found similar results for color values.

Effect of tamarind flour on total phenolic content and antioxidant activity of biscuits

Effects of tamarind flour on total phenolic content and antioxidant activity of biscuits are shown in Table 5. *T. indica* seed flour significantly affected antioxidative properties ($p < 0.05$). The antioxidant activity and total phenolic contents of biscuit samples enriched with *T. indica* seed flour were significantly higher than the control biscuits ($p < 0.05$). As previously described in Sect. 3.1., roasting degree increased the antioxidative properties of biscuit samples significantly owing to the non-enzymatic browning reactions causing new antioxidative compounds ($p < 0.05$).

Effects of tamarind flour on textural characteristics of biscuits

Effects of tamarind flour on textural properties of biscuit samples are shown in Table 4. *T. indica* seed flour significantly affected the hardness and fracturability of biscuits ($p < 0.05$). Since they are mainly related to freshness, fracturability and hardness could be used to evaluate the textural properties of biscuit samples (Bolek 2020). The hardness and fracturability of biscuit samples enriched with *T. indica* seed flour were significantly higher than the control biscuits ($p < 0.05$). This may be due to the high fiber contents of *T. indica* seeds which form more compact biscuit texture (Martínez-Cervera et al. 2011). As the roasting degree of *T. indica* seeds increased, the hardness and fracturability values of biscuits decreased significantly ($p < 0.05$). This may be due to the reduced water content (Nikzadeh and Sedaghat 2008).

Effects of tamarind flour on sensory properties of biscuit samples

Effects of *T indica* seed flour on sensory values of biscuit samples are shown in Table 6. *T. indica* seed flour increased the sensory scores of biscuits. However, the increase was not significantly ($p > 0.05$). On the other hand, *T. indica* seed flour roasted for 8 min significantly increased the sensory scores of biscuit samples ($p < 0.05$).

Table 5 Effects of tamarind seed flour on total phenolic content and antioxidant activity of biscuits

Roasting degree	Antioxidant activity (% inhibition)	Total phenolic content (mg GAE/ 100 g)
$T_{control}$	5.52 ± 0.04[d]	149.12 ± 0.05[d]
$T_{0\ min}$	15.52 ± 0.03[c]	162.21 ± 0.05[c]
$T_{8\ min}$	19.20 ± 0.05[b]	174.18 ± 0.08[b]
$T_{16\ min}$	23.02 ± 0.01[a]	190.02 ± 0.06[a]
$T_{24\ min}$	22.62 ± 0.02[a]	189.05 ± 0.04[a]

Mean of three determination ± standard error. Means followed by the same letters in the same line do not differ at the level of 95% of probability

Table 6 Sensory properties of biscuits

Roasting degree	Appearance	Odor	Texture	Flavor	Overall impression
$T_{control}$	4.02 ± 0.03^b	4.10 ± 0.02^b	4.05 ± 0.02^b	4.14 ± 0.01^b	4.05 ± 0.04^b
$T_{0\ min}$	4.10 ± 0.02^b	4.16 ± 0.02^b	4.12 ± 0.02^b	4.22 ± 0.04^b	4.15 ± 0.10^b
$T_{8\ min}$	4.63 ± 0.01^a	4.70 ± 0.01^a	4.58 ± 0.01^a	4.68 ± 0.01^a	4.80 ± 0.08^a
$T_{16\ min}$	3.50 ± 0.01^c	3.38 ± 0.03^c	3.40 ± 0.02^c	3.55 ± 0.02^c	3.30 ± 0.06^c
$T_{24\ min}$	2.81 ± 0.01^d	2.15 ± 0.02^d	1.69 ± 0.01^d	2.16 ± 0.01^d	2.01 ± 0.07^d

Mean of three determination ± standard error. Means followed by the same letters in the same line do not differ at the level of 95% of probability

This could be explained by Maillard reactions products which cause the desired aroma and flavor compounds. However, a roasting time of longer than 8 min caused a decrease in the sensory scores of the biscuits. The biscuit samples enriched with *T. indica* seed flour roasted for 24 min decreased the sensory scores of biscuit samples below 3. Since the 3 value is the middle point in the hedonic scale, the *T. indica* seed flour roasted for 24 min caused unacceptable biscuits in terms of sensory properties.

Conclusion

In this study possibility of using *T. indica* seed flour on biscuit formulation was investigated. The results of this study demonstrated that, it is possible increasing the fiber and protein contents of biscuits by using *T. indica seed* flour. Moreover, addition of *T. indica* seed flour to the biscuits increased the antioxidant activity significantly ($p < 0.05$). Roasting process developed the sensory and antioxidative properties of *T. indica* seed flour. However high roasting degree caused unfavorable effect on sensory properties. As a practical and energy-saving method, microwave roasting was used successfully for roasting process.

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