



Characterization of Physicochemical, Antioxidant, and Sensory Quality of Cookies Enriched with Microencapsulated Ginger Extracts as a Functional Ingredient

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Abstract

The ginger root is famous for its impact on food and antioxidant effects. The spicy flavor limits ginger's utilization in some food products as a result this research aims to assess the influence of incorporating micro-encapsulated ginger extract M-EG prepared by co-crystallization using maltodextrin as the encapsulating agent on the physicochemical, antioxidant, and sensory quality of cookies. Among the phenolic compounds identified on ginger extract by HPLC Catechin and Gallic acid showed the maximum concentration of 706.21(μg/g) and 650.34(μg/g), respectively. Rutin was found at 75.62 (μg/g) as a flavonoid compounds group. Microcapsules of ginger extract M-EG prepared by co-crystallization using maltodextrin as the encapsulating agent exhibited 77.66% encapsulation efficiency. The surface morphology of M-EG showed irregular shapes of small aggregates on the surface of larger clusters of sharp edges with porous structures. Different weight replacements (0, 10, 25, and 50%) of sugar by M-EG were used, and the prepared cookies were assessed for physicochemical properties, the content of total phenols, antioxidant capacity (based on different radical assays), and sensory quality. Cookie's proximate composition revealed that moisture, ash, fat, and crude fiber contents in the cookies increased slightly but significantly by increasing the M-EG content. Antioxidant profile including total phenol and total flavonoid of M-EG cookies showed enhanced antioxidant capacities associated with the increase of M-EG content. Desirable attributes were noticed for M-EG cookies like increased diameter, decreased thickness, and higher spread ratio. Sensory scores of the taste for cookies ranged from 7.2 to 8.4 and there were non-significant differences in taste for the 10% and 25% M-EG cookies as compared with the control. The results showed that the replacement of sugar by micro-encapsulated ginger extract M-EG, using maltodextrin as a wall agent, is a promising approach for developing pleasant novel products enriched in phenolic compounds and acceptable for regular cookie consumers.

Keywords: Encapsulations; ginger extract; functional cookies; antioxidants

1. Introduction

Plant polyphenols a wide family of phytochemicals and a major class of secondary metabolites, have a beneficial health-enhancing effect (Garcia-Alonso *et al.*, 2022). Consuming plant foods high in polyphenols, may protect against cancer, type II diabetes, heart disease, and other health problem (Chen *et al.*, 2023; Durazzo *et al.*, 2019; Rothwell

et al., 2015). Antioxidants are molecules that exist in foods that prevent unstable molecules termed free radicals from forming as a result of oxidation processes within the human body (Ademiluyi and Oboh, 2012). These compounds are related to disorders like heart and liver diseases and cancer (Oboh and Adefegha, 2010). Synthetic antioxidants used to inhibit free radicals have been associated with adverse impacts (Cornwell *et al.*, 1998; Shahidiet *et al.*, 1992), which makes the utilization of natural

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antioxidants interesting. Ginger (*Zingiberofficinale* Roscoe) is a flowering plant whose ginger root, or rhizome, is one of the most widely used spices and has a range of bioactive ingredients with various pharmacological, and biological impacts and possesses antimicrobial properties and antioxidants which explored in recent years (Ghasemzadeh *et al.*, 2010; Talebi *et al.*, 2021; Jan *et al.*, 2022). Ginger contains a variety of potentially bioactive compounds e.g. gingerols, and their related dehydration products, shogaols, as well as volatile oils like sesquiterpenes and monoterpenes (Semwal, 2015).

Oleoresin ginger is a ginger product that has been extracted using an organic solvent. It contains both volatile and nonvolatile compounds, and Gingerol and shogaol are the main compounds of oleoresin ginger, which give ginger its hot or fiery flavor (Ravindran *et al.*, 1994). Ginger oleoresin contains beneficial active ingredients, so it is commonly applied in the foodstuff, cosmetics, and pharmaceutical industry sectors. Numerous studies have used ginger's bioactive components as antioxidants, antimicrobials, and anti-cancer (Abdullahi *et al.*, 2020; Azeez and Lunghar 2021; Zhou *et al.*, 2022).

The bioactive compounds can be delivered by Microencapsulation, as one of the stabilization techniques, which enhances their handling properties (Calvo *et al.*, 2011). Because of its unique properties, encapsulation via co-crystallization is a potential approach to protecting receptive bioactive molecules such as phenolics. Microencapsulation as a technology protects active ingredients and flavor components from destructive changes and environmental effects, and the functional compounds as core preserved by the coating material (Jyothi, *et al.*, 2010). It is employed to maintain the stability, bioactivity, and bioavailability of active ingredients (Sansone *et al.*, 2011, Schweiggert *et al.*, 2008).

Product development using microencapsulation methods could lead to a promising compound with higher stability, efficiency, and effective release (Penget *et al.*, 2023). To achieve an ideal structure encapsulating material may be utilized singly or in combination with other encapsulating material (Fernandes, *et al.*, 2012). Encapsulated materials such as maltodextrin, gum Arabic, pectin, and guar gum are commonly used to encapsulate bioactive

compounds (Ravichandran *et al.*, 2014). Among the many microencapsulation techniques spray drying is a way to protect bioactive compounds from degradation, improve compounds' solubility, and mask unpleasant flavors (Anthero *et al.*, 2021).

Co-crystallization of bioactive ingredients in sucrose is an innovative and uncomplicated technology that offers a cost-effective approach to enhance the solubility, dispersibility, and hygroscopicity of the encapsulated material (Sanjay *et al.*, 2014). The sucrose crystals structure changes during this process Changed into an irregular, agglomerated, and porous structure has lot of empty space and surface area which allows for incorporation of active ingredient (Savjani, 2015). Furthermore, this technique has the potential to efficiently convert liquid pre-emulsion into sucrose or dry granules. Typically, proteins and polysaccharides are utilized as food wall materials in the encapsulation of bioactive compounds Maltodextrin is one of the widespread forms of polysaccharide. It has a highly soluble, neutral flavor, low cost, and low viscosity at high concentrations; however, low emulsifying properties (Mahdavee *et al.*, 2014).

The major component widely used in this approach is sucrose, which is often utilized in many food production processes (Sarabandi *et al.*, 2019). The spicy flavor limits ginger's utilization in some food products although it has antioxidant properties as a result this study aims to characterize of physicochemical, antioxidant, and sensory quality of cookies enriched with microencapsulated ginger extracts as a functional ingredient using maltodextrin as a wall material for microencapsulation of the ginger extract by using co-crystallization method which is considered a promising approach for developing a pleasant novel product

2. Experimental

2.1 Materials

Fresh raw rhizomes, wheat flour, sugar, margarine, powdered milk, baking powder, salt, and Eggs were obtained from a local marketplace. Fresh raw rhizomes were cleaned, peeled, and then dried in the

oven at 50°C. Then dry ginger was powdered and sieved through a 40-mesh screen.

2.2 Methods

2.2.1. Extraction procedure of ginger polyphenol compounds

Extraction of polyphenols from ginger powder by ultrasonic was done in an ultrasonic bath RK103H (BANDELIN SONOREX, Germany). For one hour, 50 g of ginger powder was sonicated in 300 ml of ethanol 95% at the temperature of the room. The extract was then concentrated by rotary evaporation at 40°C under vacuum until dry.

2.2.2. HPLC Analysis of phenolic content (PC)

An Agilent 1260 series was utilized For the HPLC analysis. The separation process was applied to a Kromasil C18 column (4.6 mm x 250 mm i.d., 5 m). The mobile phases were water (A) and 0.05% trifluoroacetic acid in acetonitrile (B), flowing at a rate of 1 ml/min. The mobile phase was determined using a linear gradient in the following order: 0 minutes (82% A); 0-5 minutes (80% A); 5-8 minutes (60%) A; 8-12 minutes (60%) A; 12-15 minutes (85% A); and 15-16 minutes (82% A). The multi-wavelength detector was used at the visible region at 280 nm. A volume of 10 μ was used for each sample solution during the injection procedure. The temperature of the column was kept at 35 °C.

2.2.3. Preparations of micro-encapsulated ginger extract (M-EG)

Micro-encapsulated ginger extract (M-EG) was prepared using maltodextrin as a wall material by the traditional method called co-crystallization which is based on solvent evaporation by heating (López-Córdoba *et al.*, 2014). Maltodextrin syrup was concentrated by heating during stirring till a concentration higher than 95°Brix was achieved using a hot plate with a magnetic stirrer. The heat was turned off and a Cole Parmer high shear mixer at position 1 was then used, and the core ingredient ginger extract polyphenol was added to the concentrated maltodextrin at ratios of 100g of phenolic crude extract/kg maltodextrin. Stirring was

continued till crystallization occurred, and the heat of the mixture led to water elimination, forming granules. Then, the drying was carried out using an oven set at a temperature of 40 °C for duration of 15 hours. The co-crystals formed were milled and sieved into finely ground powder and kept in polythene bags until examination.

2.2.4. Encapsulation efficiency (EE)

The phenolic content (PC) before and after encapsulation, was evaluated to determine encapsulation efficiency (EE %). Five grams of substance were dissolved in ethanol (70% v/v), and TPC levels were calculated using mean values of triplicate assays (Adeset *et al.*, 2012).

2.2.5. Surface Morphology Analysis for Microcapsules

Scanning electron microscope (SEM) (Quanta FEG 250 SEM; Thermo Fisher Scientific, Oregon, USA) was used to examine the surface morphological characteristics of M-EG powder at an accelerating voltage of 10.0 kV according to the procedure of Ferreira *et al.*, 2007 The digital images were taken at magnifications of 150x and 1000x, respectively.

2.2.6. Preparation of cookies with M-EG

Cookie samples were produced by substituting 10%, 25%, and 50% of sugar with M-EG. The cookies have been made using the recipe established by Eberet *et al.*, (2015), with a few modifications noted in Table 1. In an electric blender sugar and margarine were blended on medium speed until soft and foamy cream was formed. While mixing, 1 whole egg and powdered milk were poured. Then, mix Wheat flour, baking powder, and salt into the dough in a gradual process. On a lightly oiled aluminum cookie sheet, the dough was rolled to a 6 mm thickness and cut using a 50 mm diameter circle cookie cutter, with extra dough eliminated. In a preheated oven set at 180°C, cookies were baked for 10 minutes, then allowed to cool down until they reached ambient temperature, and kept at 4°C before being investigated. Based on preliminary data M-EG

powder was set and optimized for the preparation of functional cookies.

Table 1: Formula used for cookie preparation

Ingredient	Amount (g)
Wheat flour	100
Sugar	35
Margarine	40
Milk powder	10
Baking powder	2
Salt	0.5
Egg	60

2.2.7. Proximate chemical composition of cookies

Standard methods were used to determine the sample's proximate composition according to (AOAC, 2007). The estimation of carbohydrate content has been done using the difference method.

2.2.8. Antioxidant properties of cookies

2.2.8.1. Antioxidant activity

According to Parsaei *et al.*, (2017), the antioxidant activity of cookie samples was assessed via the measure of radical scavenging ability by using the stable radical 2,2-diphenyl-1-picrylhydrazyl (DPPH). The radical scavenging activity was determined and the sample's free radical inhibition % can be expressed using the formula provided. (Salmanian *et al.*, 2014):

$$\% \text{ Inhibition} = [(A_0 - A_t) / A_0 \times 100]$$

Where A_0 is the control absorbance of (without sample) and A_t is the sample absorbance.

2.2.8.2. Total Phenolic content

The determination of Phenolic content in the extracts was done as reported by Omoba *et al.* (2015). The TPC was calculated as mg of gallic acid equivalents (GAEs) per 100 g using gallic as the standard for calculation.

2.2.8.3. Total flavonoid content

Total flavonoid content was carried out using the method of Ivaniđová *et al.* (2018). A spectrophotometer the UNICO UV/VIS-2100 (Dayton, USA) was used to determine the absorbance at 415 nm after 30 minutes in complete darkness. The

results were represented in mg/100g RE (Rutin equivalents), using Rutin as a standard.

2.9. Physical properties of cookies

According to Approved Method 10-50D (AACC, 2000), cookie diameter (D), thickness (T), and spread ratio were used to investigate the baking characteristics of cookies. To measure the diameter of the cookies, six cookies were set next to each other, to evaluate total diameter. The new diameter of each cookie was evaluated after each one had been rotated 90° and the diameter's average was noted. Six cookies were stacked on top of the others and then restacked four times to estimate the thickness of the cookies and the thickness mean was recorded. The spread ratio was estimated by dividing the cookie diameter by the cookie thickness.

2.10. Sensory evaluation of cookies

A 20-person panel of students and staff from the Department of Food Technology, National Research Centre, evaluated the cookies' sensory attributes by the method of a 9-point Hedonic scale for multiple variables such as color, texture, crispness, taste, flavor, and overall acceptability. For evaluating the excellence, the mean scores of 10 qualified trained judges were taken to be considered (Awasthi, 2012).

2.11. Statistical Analysis.

SPSS 18.0 was used to analyze the data. Duncan's multiple range tests at a 95% confidence level were used to distinguish means with significant variations. (SPSS for Windows, 2007, SPSS Inc., Chicago, USA)

3. RESULTS AND DISCUSSION

3.1. Identification of phenolic compounds (PC) by HPLC

Thirteen phenolic compounds were identified and determined as shown in Fig. 1 and Table 2.

Among the phenolic compounds, Catechin and Gallic acid showed the maximum concentration of 706.21($\mu\text{g/g}$)and 650.34($\mu\text{g/g}$), respectively. Rutin, a bioflavonoid glycoside with strong antioxidant properties, was found at 75.62 ($\mu\text{g/g}$) as a flavonoid compounds group. Tohma *et al.* (2016) found authentic phenolic acids such as gallic acid, ellagic, coumaric acids, and vanillin in (EEG) ethanol extract of ginger.

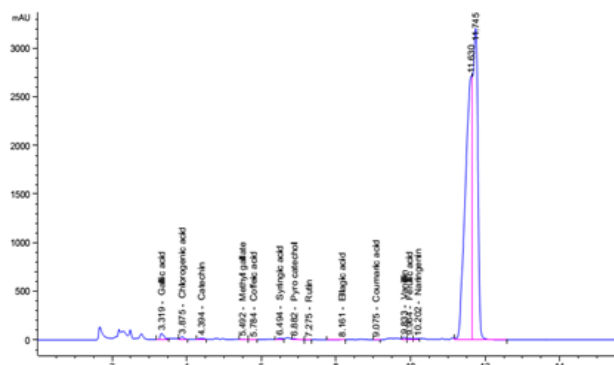


Fig. 1. HPLC chromatograph for microencapsulated ginger extract

Table (2) HPLC analysis of phenolic antioxidant compounds in ginger extract.

Compounds	Conc. ($\mu\text{g/g}$)
Gallic acid	650.34
Chlorogenic acid	437.77
Catechin	706.21
Methyl gallate	37.30
Coffeic acid	44.47
Syringic acid	64.21
Pyro catechol	245.49
Rutin	75.62
Ellagic acid	69.89
Coumaric acid	8.17
Vanillin	60.14
Ferulic acid	98.64
Naringenin	141.62

3.2. Encapsulation characterizations

3.2.1. Encapsulation efficiency (EE)

Encapsulated efficiency (EE) of M-EG prepared by co-crystallization using maltodextrin as the encapsulating agent reached 77.66% EE of ginger phenolic compounds. EE of 76% was achieved for

the encapsulated ginger oil in alginate-based shell materials (Atencio *et al.*, 2020). In the case of microencapsulation of betacyanin extracted from dragon fruit peel by the process of complex coacervation, EE for maltodextrin-based encapsulates was 80.53%. The increased encapsulation efficiency demonstrated that the colloidal system's core material had been successfully captured by the formulation process. (Raj and Dash, 2022). Rai *et al.* (2021) reported that the EE of ginger oleoresin in the co-crystallized sugar cubes was 43.01%. Many variables can impact encapsulation efficiency, including the encapsulating process, coating material qualities, microcapsule wall viscosity, bioactive ingredients, and interactions of compounds (Jyothi *et al.*, 2010).

3.2.2. Scanning electron microscope (SEM)

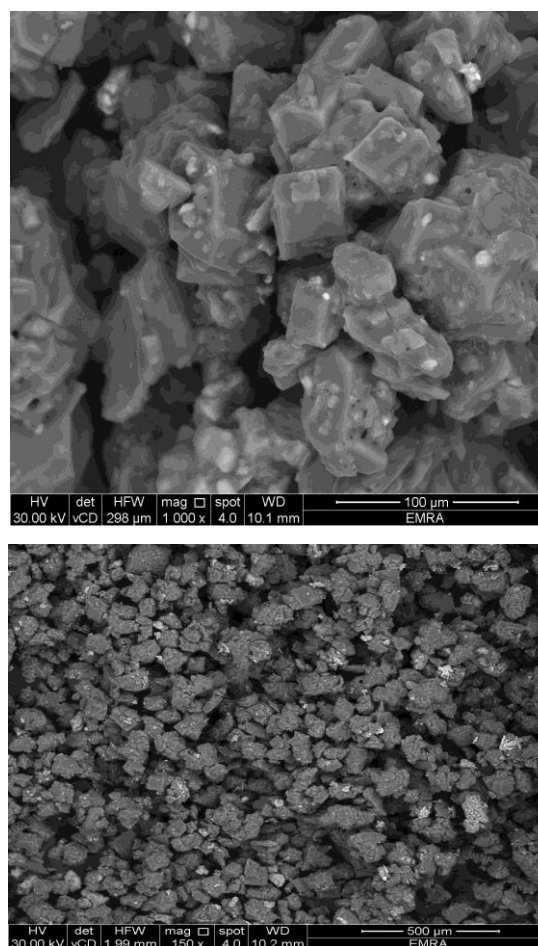


Fig.2 SEM of encapsulated M-EG particles by co-crystallization

The surface morphology of M-EG is presented in Fig. 2. M-EG showed irregular shapes of small

aggregates on the surface of larger clusters of sharp edges with porous structures. The collisions of wall material particles throughout the drying process result in the accumulation of smaller particles on the surface of large ones (Lourenço *et al.*, 2020).

It is well known that evaporative co-crystallization leads to the formation of a crystalline shape with a porous structure; for example, in the co-crystallization of sucrose as a wall material, its crystalline structure alters to porous irregular aggregated crystals, providing a porous matrix where encapsulation occurs (Karangutkar & Ananthanarayan, 2020).

These pores act as a trap for the ginger extract inside the maltodextrin crystals. A similar morphology was obtained for pomegranate peel extract encapsulated in sucrose prepared by the same method (Chezanoglou *et al.*, 2023). In literature, encapsulated maltodextrin prepared by a spray dryer usually has spherical shapes but, in this article,

encapsulated maltodextrin showed different morphology due to the preparation by evaporative co-crystallization where the temperature has a role in the morphology of the form M-EG (Both *et al.*, 2018)

3.3. Proximate chemical composition of cookies

The current research was done to study the suitability of M-EG incorporation on qualitative attributes of cookies. Cookies' proximate composition is summarized in Table 3. The findings reveal a slight increase in moisture content in the case of M-EG cookies. The highest fat content was found in 50% M-EG, (12.88%) whereas the fat content of control was the lowest (11.39%).

The ash content enhanced increasingly with the increase of M-EG content. The M-EG 50% sample had the greatest content of ash (2.37%), whereas, the control sample exhibited the lowest fat content (1.67%).

Table 3: Proximate Chemical composition of cookies incorporated with M-EG.

Samples	Moisture	Fat	Protein	Ash	Crude fiber	Carbohydrate*
Control	8.11 ± 0.01 ^b	11.39 ± 0.61 ^b	10.06 ± 0.04 ^a	1.67 ± 0.03 ^c	0.21 ± 0.03 ^d	68.54 ± 0.62 ^a
M-EG 10%	9.23 ± 0.03 ^a	12.03 ± 0.25 ^b	9.96 ± 0.07 ^{ab}	2.02 ± 0.07 ^b	0.32 ± 0.02 ^c	66.42 ± 0.40 ^b
M-EG 25%	9.09 ± 0.27 ^a	11.53 ± 0.07 ^b	9.80 ± 0.17 ^b	2.27 ± 0.17 ^{ab}	0.42 ± 0.02 ^b	66.87 ± 0.15 ^b
M-EG 50%	8.01 ± 0.26 ^b	12.88 ± 0.01 ^a	9.77 ± 0.15 ^b	2.37 ± 0.23 ^a	0.50 ± 0.02 ^a	66.45 ± 0.24 ^b

M-EG: Microencapsulated Ginger Extract, Data are the mean ± SE, n = 3, Values followed by the same letters in the same column are not significantly different (p ≤ 0.05). *: calculated by differences.

3.4. Antioxidant properties of cookies

The antioxidant properties such as antioxidant activity, the total phenolic content, and total flavonoids of M-EG cookies, and the control are given in Table 4.

3.4.1. Antioxidant activity

All the cookie extracts exhibited DPPH radical scavenging potentials Table 4. DPPH scavenging capacities for all cookies achieved significant values compared with control samples. The cookies with 50% M-EG showed strong free radical scavenging characteristics when compared with lower M-EG content cookies. The DPPH scavenging potential of the cookies with 25 and 10% M-EG was not significantly different. It is due to the incorporation of M-EG for the preparation of the cookies which led

to a considerable enhancement in the antioxidant activity of cookies.

Obohet *et al.*, (2010) reported that ginger is an excellent resource of phytochemicals with strong antioxidant activities and can be extracted by water.

3.4.2. Total Phenolic Content

The main class of antioxidants found in human diets is phenolic compounds. They can eliminate free radicals, act as chelating metal catalysts, and prevent oxidation (Amicet *et al.*, 2003). The total phenolic content in cookie extracts ranges from 152.86 to 367.28 mg GAE/100g as shown in Table 4.

There are non-significant variations in the phenolic content of 10% M-EG cookies compared with the 25% M-EG. However, the cookies with 50% M-EG had significantly greater total phenolic content than other samples under investigation. The results of this assay indicated that the contents of total phenolic in

cookies fortified with M-EG were significantly higher than the control. The improvement was almost 2 times in the 50% of M-EG-fortified cookies (from 152.86 to 367.28 mg GAE/100g). Improvements in

the phenolic content of the cookies were an additional improvement besides their total radical scavenging abilities.

Table 4: Antioxidant properties of cookies incorporated with ginger encapsulation

Treatments	DPPH (%)	TPC (mg GAE/100g)	TFC (mg RE/100g)
Control	25.29±.50 ^c	152.86±1.91 ^c	106.11±1.18 ^d
M-EG 10%	55.80±.31 ^b	209.95±.94 ^b	146.76±1.93 ^c
M-EG 25%	55.15±.24 ^b	211.61±2.28 ^b	156.76±1.93 ^b
M-EG 50%	58.15±1.02 ^a	367.28±1.53 ^a	197.43±1.81 ^a

M-EG: Microencapsulated Ginger Extract, Data are expressed as means ± SE (n = 3). Mean values in the same column within each parameter bearing the same superscript do not differ significantly (P > 0.05).

3.4.3. Total flavonoid content

shows the total flavonoid content of the M-EG cookies samples and the control sample. The findings showed that adding M-EG resulted in a significant (P ≤ 0.05) increase in their flavonoid levels. Total flavonoid content ranged from 146.67 to 197.43 mg RE/100g for M-EG cookies compared to 106.11 mg RE/100g in the control sample. The 50% M-EG cookies showed enhanced total flavonoid content by 85% compared to the control sample.

Generally speaking, cookies incorporated with encapsulated ginger extract achieved a significant increase in the content of total phenolic and flavonoid contents as well as the antioxidant activity more than the control cookie. The microencapsulation procedure for M-EG improved the antioxidant properties of cookie samples.

Kaderideset *al.*, (2020), examined the polyphenols extracted from pomegranate peel for their potential to encapsulate and their incorporation in cookies. Their results indicated that the encapsulating procedure is promising progress for functional food products due to the enhanced antioxidant activity and stability during storage.

Similar were observed by Saponjacet *al.*, (2016), who found that encapsulated bioactive compounds of sour cherry pomace had a good effect on the functional properties of incorporated cookies and their shelf life. On the other hand, the carrier agent used in the encapsulation process can play a role in improving and maintaining antioxidant activity. The Maltodextrins are ideal carrier agents because they are bland in flavor, relatively affordable, thermally stable, have low viscosity in large amounts, and give excellent oxygen protection (Fioramontiet *al.*, 2017;

Carneiroet *al.*, 2013). Maltodextrin microcapsules additionally inhibit singlet oxygen and protect the core material from antioxidants (Fariaet *al.*, 2010).

3.5. Physical properties of cookies

Table 5 presents cookies' physical characteristics, including their diameter, thickness, and spread ratio. According to the findings of these experiments, there are significant differences in terms of dimension, thickness, and spread ratio between cookies containing M-EG and control (p ≤ 0.05).

Table 5: physical properties of cookies incorporated with microencapsulated ginger extract

Treatments	Diameter D (mm)	Thickness T (mm)	Spread ratio D/T
Control	52.92±1.48 ^c	6.95±.06 ^a	7.61±.28 ^c
M-EG 10%	56.00±.31 ^b	6.5±.15 ^b	8.50±.19 ^b
M-EG 25%	57.17±.41 ^{ab}	6.5±.136 ^b	8.73±.21 ^{ab}
M-EG 50%	58.95±.74 ^a	6.46±.15 ^b	9.12±.33 ^a

Data are the mean ± SE, n = 3, Mean values in the same column bearing the same superscript do not differ significantly (P ≤ 0.05).

The increase in the M-EG % had a significant effect on the samples' diameters (P ≤ 0.05), Table 5.

The largest diameter was found in 50% M-EG (58.95 mm) while 10% M-EG (56.00 mm) and the control samples (52.92 mm).

The increased diameters in the case of M-EG cookies compared to the control sample may be

because of the higher polarity and polysaccharide solubility of maltodextrin-containing microcapsules which are considered a carrier agent (Zhang *et al.*, 2014). The control had the maximum thickness of 6.95 mm across samples, whereas 10, 25, and 50% M-EG had the lower thicknesses (6.00, 6.00, and 6.46 mm, respectively).

Table 5. showed that the addition of M-EG during cookie production resulted in no significant difference ($P \leq 0.05$) in thickness between them. It is widely recognized that cookies with high spread ratios are preferable. In the current study, it was observed that 25% and 50% M-EG cookies had higher spread ratios of 8.73 and 9.12, respectively, with a significant ($P \leq 0.05$) enhancement than 10% M-EG and control cookies, which recorded 8.50 and 7.61, respectively.

3.6. Sensory evaluation of cookies

Sensory attributes of baked cookies with various M-EG content were investigated in comparison to control cookies, and the findings are shown in Fig.3. Based on ANOVA results, the color scores for M-EG cookies (7.8–7.2) were lower than the control (8.0). The color of food samples has an impact on sensory aspects for consumers. The current study's findings show that panelists perceived the color difference among treatments as a result of the yellow color of incorporated M-EG. At the same time from

The flavor of examined cookie samples was lightly reduced in scores and there was no significant ($P \geq 0.05$) difference with control cookies. The addition of M-EG to the formulas did not affect the texture or crispiness. The panelists were unable to find the difference between the textures of the control and the M-EG cookies.

All formulas were accepted and recorded scores higher than 4 (neither like, nor dislike) of taste for cookies, ranging from 7.2 to 8.4. There were non-significant differences in taste for the 10% and 25% M-EG cookies as compared with the control. The lower score of 50% M-EG may be related to the slightly spicy taste of ginger. From the data in the same figure, it could be found that there is a non-significant ($P \geq 0.05$) variance in overall acceptability between cookies incorporated with 10% and 25% of M-EG and control.

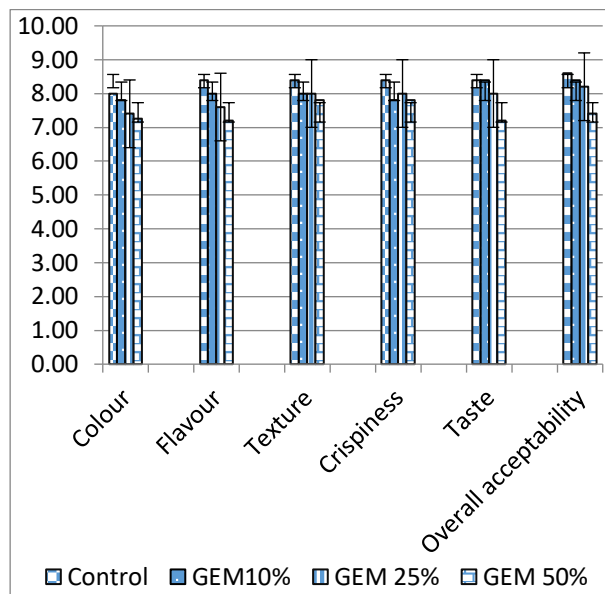


Fig. (3). Sensory characteristics of prepared cookies with different levels of M-EG

The overall acceptability of cookies containing 10%, 25%, and 50% of M-EG progressively reduced in scores 8.4, 8.2, and 7.4, respectively in comparison to the control cookies which had 8.6. Therefore, M-EG has potential use in cookies applications. In this context, Raiet *al.* (2021), the Co-crystallization approach was utilized to produce the encapsulating ginger oleoresin in co-crystallized sucrose with Arabic gum and used in flavored tea, it also mentioned that flavored sugar cubes can be used to flavor drinks, sweets, and baked products, and others food products.

4. CONCLUSIONS

Ginger is a popular healthy food with a high level of phenolic compounds and bioactive substances that boost health. Despite the unique health benefits of ginger, its pungent taste limits its use in many food industries. This study explored the possibility of benefiting from the health properties of ginger through the encapsulation of its phenolic compounds in maltodextrin to mask its pungent taste. In cookie production, the replacement of sugar by encapsulated ginger extract in maltodextrin ensures the incorporation of useful bioactive compounds into the

product. Bioactive compounds from the ginger extract were successfully encapsulated in maltodextrin by the traditional facile evaporative co-crystallization method. The distinctive use of maltodextrin as a wall material for the encapsulation of bioactive compounds is a promising approach because it is odorless and colorless, and thus it does not affect the sensory properties of various food products. There are favorable characteristics noticed for M-EG cookies such as increased diameter, decreased thickness, and higher spread ratio. Antioxidant profile including total phenol and total flavonoid of M-EG cookies showed enhanced antioxidant capacities associated with the increase of M-EG content. We suggested that the replacement of sugar with 25 % M-EG is a good functional ingredient or food component that has favorable physicochemical properties, antioxidant effects, sensory acceptability, and it is potential use in cookie applications. It is very promising to use M-EG in other food applications in the future.

5. Conflicts of interest

There are no conflicts to declare

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