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SYNERGISTIC EFFECT OF GINGER AND CLOVE SPICES ON THE ANTIOXIDATIVE POTENTIALS AND ACCEPTABILITY OF TAMARIND PASTE

BY

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Abstract

Sudden increase in prices of soft drinks, consumer's request for drinks with anti-oxidative potentials and increasing concern about under-utilization of readily available tamarind fruits demand for formulation of innovative product from this fruit. The aim of this research is to determine synergistic effect of ginger and clove spices on the anti-oxidative potentials and the acceptability of tamarind paste. Tamarind was collected, sorted, washed and soaked in water for easy pulp extraction. Ginger and cloves were then milled and added to the tamarind pulp in various ratios to increase the anti-oxidative potentials using design expert to make seven samples and 100% tamarind as the control. The ratios of inclusion from the design expert ranged from (3-10% and 2-10% for clove and ginger respectively). Paste was obtained by freeze drying the spiced tamarind pulp. Anti-oxidative potentials (2, 2-Diphenyl-1-picrylhydrazyl (DPPH), total phenol content, total flavonoid content and total antioxidant content), vitamin C, solubility and sensory properties were determined using standard methods. Data obtained were analysed using ANOVA. DPPH ranged from 22.37 to 105.22µg/100g while total flavonoids ranged from 23.68 to 47.25mg/100g. Total antioxidant, total phenolic and vitamin C contents increased significantly in the spiced tamarind paste. Solubility test showed that the spices do not have significant effect on the solubility of tamarind paste but the water temperature does. The results obtained in this study revealed that spicing tamarind paste improved its antioxidant potentials and acceptability of the tamarind paste. Tamarind paste with 10% ginger had the highest sensory scores and was most preferred by the panelists.

Keywords: Tamarind paste, Ginger, Clove, Antioxidants, Freeze drying

Introduction

Tamarindus indica L. (Fabaceae, Caesalpinioideae), or tamarind, is a tropical plant native to Africa. The plant has long been used as a food and herbal medicine. Its fruit pulp is well-known as a good source of vitamins, minerals, and organic acids. Tamarind fruit possesses several pharmacological activities, such as antifungal, antiasthmatic, hepatoprotective, and wound healing activities (Shehu *et al*., 2006) . Its leaf, stem bark, root bark, and seed, have also been reported as medicaments, e.g., antibacterial, antihyperlipidemic, antiulcer, anticancer, antifungal, wound healing, hepatoprotective and immunopotentiation agents (Mahmudah *et al*., 2017). There are various chemical constituents in *T. indica*. The fruit pulps contain furan derivatives, carboxylic acid, phlobatannin, grape acid, apple acid, flavonoids, pectin and sugars (Adenıyı *et al*., 2018) . Tamarind fruits are rarely used directly, but usually soaked in water for some times, then followed by manual pulp extraction. This process is not only clumsy but unhygienic as well. However, tamarind pulp in powder form can prove better in this regard. In powder form, it has many benefits and economic potentials, it can as well be packaged neatly thus eliminating residue disposal. In addition, dry tamarind fruit has longer shelf life at ambient temperature due to low water activity; low logistic expenditures due to reduced weight and volume, and easy to use, compared with squeezing of pulp from tamarind fruit Jittanit *et al.*, 2011.

Basically, the tamarind pulp contains 20% moisture, 6% fiber and 67 % carbohydrates. However, tamarind pulp like other fruit juices contains high proportion of low molecular weight components such as fructose, glucose, and tartaric acid which can cause stickiness problem during spray drying. The stickiness problem is mainly due to the low glass transition temperature of these components which is about 5, 31 and 18 °C for fructose, glucose, and tartaric acid respectively (Muzaffar *et al* ., 2017). Due to this, the spray drying of tamarind pulp is complex. During drying at temperatures normally prevailing in spray dryers, they tend to stick to the walls of the dryer and finally give a paste like structure instead of powder. Thus, problems like low product yield and certain operational problems can be encountered during spray drying of tamarind pulp. Tamarind paste is the processed pulp of tamarind fruit. It has many culinary uses including a flavoring for chutnies, curries, and as a souring agent that has the ability to provide a tangy acidity to dishes along with mildly sweet notes. Tamarind paste is mostly used in Asian and Middle Eastern cooking to give a slightly sour flavor to dishes. It is made from sour, dark, sticky fruit that grows in a pod on a tamarind tree. It can be reconstituted with water to form juice; it can also be added to foods such as pap to increase its nutritive quality.

On the other hand, spices are dried seeds, fruits, roots, barks or flowers of a plant or an herb used in small quantities for flavor, color or as a preservative. Moreover, for people of the world, spices stimulate appetite and create visual appeals to food. Globalization has made these spices easily available, and increasing their popularity. In addition to making food taste good, culinary spices have been used as food preservatives and for their health-enhancing properties for centuries. Spices are functional foods; thus, can be demonstrated to have a beneficial effect on certain target functions in the body beyond basic nutritional requirements (Dini,2018). Ginger, as food enhancer and traditional medicine, has been used around the world since ancient times (Moawad *et al*.,2015). It imparts aroma and flavor to food products andits acceptance by consumers is increasing due to its potential to improve the taste of ready-to-eat foods. The health-promoting properties of ginger are due to the presence of gingerols, volatile oils, shogaols and high antioxidant compounds (Jelled *et al*., 2015). Ginger is a popular single-rhizome flowering plant that is commonly used as a culinary and folk medicine (Dosoky and Setzer, 2018). The versatile benefits of ginger known to the world today are due to the rapid development of fractionation and detection technology in the field of ginger research.

Clove (*Syzygiumaromaticum)* is a precious and valuable spice of the world, the part used is basically the dried aromatic buds of flower of a tree in the family of Myrtaceae (Singletary, 2014). It is a spice commonly used for flavor and as a natural preservative in food industries due to its rich phenolic constituents like eugenol, eugenol acetate etc. These phenolic constituents possess enormous antioxidant activities, anti-glycation, antinociceptive and antimicrobial properties which enhance the bioactivities of clove spices (Idowu *et al* .,2021). Freeze drying is a low temperature dehydration process that involves freezing the tamarind paste, lowering pressure, then removal of ice from the frozen tamarind paste by sublimation to produce a dried product. Freeze drying results in high quality product (tamarind) because of the low temperature used in its processing. The original nutrients and sensory attributes of tamarind are maintained and quality of the rehydrated product is excellent (Ratti, 2008).

Antioxidants perform a critical function in the human body cells, food system and tissues by limiting oxidative destruction from toxic molecules known as free radicals (Rathod *et al* ., 2023) . Addition of ginger and clove enhances the antioxidant activity of tamarind paste and will improve the health benefits of consumers. However, there is an absence of studies investigating the synergistic effect of combining tamarind paste with other natural spices, such as ginger and clove, which are commonly used in Nigerian cuisine. Thus, addition of ginger and clove spices as a nutraceutical ingredient in fruit products, such as tamarind, could be considered. This knowledge gap

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calls for comprehensive research to establish the effectiveness of these spice combinations on the antioxidant potential of tamarind paste. Therefore, the aim of this research is to determine synergistic effect of ginger and clove spices on the anti-oxidative potentials and the acceptability of tamarind paste.

Materials and Methods

High-quality tamarind fruits were purchased from Babban Gida in Yobe state, while ginger and cloves were purchased in Ilorin, Kwara state. The materials were brought to the Food Processing Laboratory, Department of Food Science and Technology, Kwara State University for processing.

Preparation of spice powder

Ginger and cloves were sorted, cleaned, oven- dried at 60 ^{0}C, cooled and dry-milled separately using an electric blender (Marlex). The powder obtained were sieved and kept in an air-tight container (Figure 1).

Ginger and Clove spice

↓

Sorting

↓

Cleaning

↓

Oven Drying (Below 60^{0}c)

↓

Milling to powder

Figure 1: Flowchart for preparation of ginger and clove spices

Extraction of Pulp from Tamarind fruit

Fruits of tamarind were broken and pulps were separated from the seeds and other components by soaking dehulled tamarind fruits (1 kg) in a nonreactive bowl containing 2 liters of warm water (40^{0}C) for 20 minutes. Periodically, mashing of the tamarind was done .using fingers to freeing as much pulp as possible from the fiber and seeds. The mashed mixture was filtered in order to separate the fibers, membranes and seeds. The dried milled spices were added to the tamarind pulp in the varied ratios obtained from the D-optimum design expert (Table 1), and thorough homogenization was done using stirrer to ensure uniformity. The homogenized spiced tamarind pulp was freeze dried at (-40^{0}C) to obtained tamarind paste (Figure 2).

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Table 1: Experimental Design (Mixing Ratio of Tamarind powder, ginger and clove spices).

Samples	Tamarind (%)	Clove (%)	Ginger (%)
AB	87.50	6.50	6.00
CR	88.00	10.00	2.00
BW	83.50	6.50	10.00
DT	91.00	3.00	6.00
EU	95.00	3.00	2.00
IX	85.50	6.50	8.00
FR	100.00	0.00	0.00

IX = 85.5% Tamarind, 6.5% Clove, 8% Ginger
CR = 88% Tamarind, 10% Clove, 2% Ginger
BW = 83.5% Tamarind, 6.5% Clove, 10% Ginger
DT = 91% Tamarind, 3% Clove, 6% Ginger
EU = 95% Tamarind, 3% Clove, 2% Ginger
AB = 87.5% Tamarind, 6.5% Clove, 6% Ginger
FR = 100% Tamarind, 0% Clove, 0% Ginger

Antioxidant analyses of Tamarind paste

The Antioxidant analyses carried out in this study include: Total Antioxidant Content (TAC) which was assessed according to the method described by Tsegay, 2020. DPPH of the tamarind paste was determined according to (Baliyan *et al*., 2022). Procedure, Total Phenolic Content and Flavonoid Content were determined using (Bekhouche *et al*., 2022)..

Chemical Analyses

Ascorbic acid (vitamin C) was analyzed according to (Danielczuk *et al* ., 2004) method and based on the reduction of 2, 6-dichlorophenol indophenol sodium salt (DISS) by ascorbic acid(da Rocha *et al* ., 2022) , while solubility analysis was done using AOAC (2012) and the solubility of the freeze-dried tamarind paste was calculated using the formula below:
Solubility = (W2 / W1) x 100.

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Tamarind fruits

↓

Sorting/Cleaning

↓

Soaking in warm water

↓

Separation of pulp from seeds/fibre

↓

Tamarind pulp

↓

Addition of ginger and clove powder

↓

Homogenization of the powder and the pulp

↓

Lyophilization (below -40^0c)

↓

Freeze-dried tamarind paste

Figure 2: Flowchart for preparation of freeze-dried tamarind pulp

Sensory assessment

Coded tamarind paste samples were served to twenty (20) randomly selected semi-trained panelists. Each panelist was asked to assess tamarind paste samples for appearance, taste, flavour and overall acceptability using a nine (9) point's hedonic scale rating, where 1 and 9 respectively represented dislike and like extremely. Tamarind paste without spice was used as control sample.

Statistical analysis

All tests were replicated and the data obtained were statistically analyzed using the statistical package for social science (SPSS) version 16.0 package software. Significance was accepted at 0.05 probability level.

Results

Antioxidants activities of tamarind based mixed paste

The results of the antioxidant activities of the tamarind samples are presented in Table 2. DPPH contents varied significantly among the samples and it ranged from 22.37to 105.22 mg/100g. Sample CR (88% Tamarind, 10% Clove, and 2% Ginger) had the highest DPPH level while the lowest DPPH was recorded for the control sample (100% Tamarind, 0% Clove, and 0% Ginger). The results of the tamarind pastes flavonoid contents are shown in Table 2. Total flavonoids ranged from 23.68 to 47.25 mg/100g, and sample CR (88% Tamarind, 10% Clove, 2% Ginger) had the highest level of total flavonoid while the control (100% Tamarind, 0% Clove, 0% Ginger) had the lowest content. Table 2 shows the (TAC) which ranged from 3.82 mg/100g to 4.35 mg/100g. Sample CR (88% Tamarind, 10% Clove, 2% Ginger) and sample DT (91% Tamarind, 3% Clove, 6% Ginger) had the highest and lowest total antioxidant capacity respectively. Total phenolic contents of the tamarind paste spiced with ginger and clove are presented in Table 3. It varied from 51.24 mg/100g to 115.54 mg/100g with sample CR (88% Tamarind, 10% Clove, 2% Ginger) having the highest value, while the lowest total phenol content was recorded in tamarind paste sample FR (100% Tamarind, 0% Clove, 0% Ginger).

Table 2: Antioxidant contents of ginger and clove- tamarind paste

Samples	DPPH IC50 (μg/m)	Flavonoid (mg/100g)	Total antioxidant (mg AAE/g)
IX	$29.66 \pm 0.13^{1)f}$	45.62 ± 0.00^{b}	4.26 ± 0.00^{b}
CR	105.22 ± 0.26^{a}	47.25 ± 0.00^{a}	4.35 ± 0.01^{a}
BW	74.49 ± 0.66^{c}	30.44 ± 0.03^{e}	4.03 ± 0.00^{c}
EU	79.05 ± 0.12^{b}	35.29 ± 0.00^{d}	3.87 ± 0.00^{e}
FR	22.37 ± 0.41^{g}	23.68 ± 0.01^{f}	4.02 ± 0.00^{d}
AB	45.99 ± 0.69^{e}	38.63 ± 0.01^{c}	3.84 ± 0.01^{f}
DT	61.16 ± 1.06^{d}	38.63 ± 0.00^{c}	3.82 ± 0.00^{g}

Mean±SD (n=3) and different superscript letters (a-d) with the same column indicate significant differences ($p<0.05$).
Key
IX = 85.5% Tamarind, 6.5% Clove, 8% Ginger
CR = 88% Tamarind, 10% Clove, 2% Ginger
BW = 83.5% Tamarind, 6.5% Clove, 10% Ginger
DT = 91% Tamarind, 3% Clove, 6% Ginger
EU = 95% Tamarind, 3% Clove, 2% Ginger
AB = 87.5% Tamarind, 6.5% Clove, 6% Ginger
FR = 100% Tamarind, 0% Clove, 0% Ginger

Table 3: Total Phenolic content of the mixed ginger and clove spiced tamarind paste

Samples	Phenolic (mg/100g)
IX	114.08 ± 0.00^{b}
CR	115.54 ± 0.11^{a}
BW	82.63 ± 0.01^{f}
EU	83.03 ± 0.01^{e}
FR	51.24 ± 0.02^{g}

AB	95.52±0.13^{c}
DT	88.51±0.01^{d}

Mean±SD (n=3) and different superscript letters (a-d) with the same column indicate significant differences (p<0.05).
Key
IX = 85.5% Tamarind, 6.5% Clove, 8% Ginger
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Solubility and Sensory Attribute of Spiced Tamarind paste

The solubility of the spiced tamarind paste is presented on Table 4. It consistently increased with increase in temperature from 40°C to 100°C. Table 5 also shows the results of sensory properties of the tamarind paste spiced with ginger and clove powder samples. The results obtained revealed that sample FR (100% Tamarind, 0% Clove, and 0% Ginger) was significantly different (P < 0.05) from other samples with respect to flavor, taste and overall acceptability, in fact, it got the lowest scores for these attributes by the panelists. Contrarily, it had the highest rating for appearance (7.50). Sample BW (83.5% Tamarind, 6.5% Clove, 10% Ginger) had the highest sensory rating for flavor (7.90), taste (8.39), mouth feel (6.41) and overall acceptability (7.90), but not significantly different from samples IX (85.5% Tamarind, 6.5% Clove, 8% Ginger) and AB(87.5% Tamarind, 6.5% Clove, 6% Ginger) with respect to taste and mouth feel.

Table 4: Solubility of Tamarind paste spiced with ginger and clove

Samples	**Solubility (%)**			
	40°C	**60°C**	**80°C**	**100°C**
CR	12.19±0.04$^{1)c}$	14.10±0.02^{b}	20.07±0.04^{b}	25.22±0.02^{b}
AB	11.38±0.03^{e}	13.98±0.08^{b}	19.31±0.04^{d}	25.17±0.08^{b}
BW	11.10±0.02^{g}	13.08±0.29^{c}	18.81.±0.04^{e}	25.11±0.04^{b}
IX	11.25±0.13^{f}	14.03±0.00^{b}	19.34±0.05^{d}	25.20±0.06^{b}
DT	11.48±0.00^{d}	14.14±0.06^{b}	19.57±0.04^{c}	25.18±0.02^{b}
FR	12.59±0.03^{a}	15.48±0.01^{a}	21.38±0.06^{a}	27.33±0.11^{a}
EU	12.31±0.01^{b}	14.19±0.02^{b}	21.33±0.09^{a}	27.25±0.11^{a}

Mean±SD (n=3) and different superscript letters (a-e) with the same column indicate significant differences (p<0.05).

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Table 5: Sensory attributes of tamarind paste spiced with ginger and clove

Samples	Flavor	Appearance	Taste	Mouth feel	Overall Acceptability
IX	7.70± 0.68^{c}	7.30±0.68^{b}	8.40±0.70^{a}	6.40±0.70^{a}	7.70±0.68^{b}
CR	7.80±0.82^{b}	6.80±0.92^{c}	7.20±1.23^{c}	5.80±0.03^{b}	6.90±0.74^{c}
BW	7.90±0.4 ^{a}	7.30±0.67^{b}	8.39±1.14^{a}	6.41±0.82^{a}	7.90±0.68 ^{a}
DT	7.70±0.79^{c}	7.50±0.94^{a}	8.02±0.99^{b}	5.60±0.70^{c}	6.80±1.03^{d}
FR	5.70±0.68^{f}	7.50±1.05^{a}	6.40±1.17^{d}	5.10±0.55^{d}	6.70±1.06^{d}
	7.40±0.42^{d}	7.30±0.68^{b}	8.40±0.70^{a}	6.40±0.70^{a}	7.70±0.68^{b}
AB	6.67±0.42^{e}	7.5±1.05^{a}	8.02±0.99^{b}	5.60±0.70^{d}	6.81±0.68^{d}
EU					

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Discussion

Cloves exhibited strong antioxidant properties owing to the presence of high phenolic and flavonoid contents in them. The high activity may be attributed to the presence of eugenol, β-caryphyllene, vanillin, crategolic acid, tannins and flavonoids in cloves (Gupta, 2013). Tamarind is known to contain various bioactive compounds, including polyphenols and flavonoids, which contribute to its strong antioxidant potential (D'souza *et al* ., 2012) . However, addition of clove spice significantly increases the antioxidant potential. This is in line with the report of (Huang *et al 2011*) that the antioxidant activity of natural products that are high in phenolic content showed high DPPH values. Flavonoids are known for their high antioxidant properties (Cushnie & Lamb, 2005) and its presence in the tamarind pastes might contribute to the increased flavonoid contents recorded in the tamarind pastes used for this study. High flavonoid content recorded in tamarind paste with high clove powder is in accordance with the findings of (Mashkor, 2015) that reported 22.53 mg/100 g for total flavonoids in clove stem and fruit pulps. Conversely, the lowest total flavonoid content in the non-spiced tamarind pulp (100% Tamarind) indicates that clove

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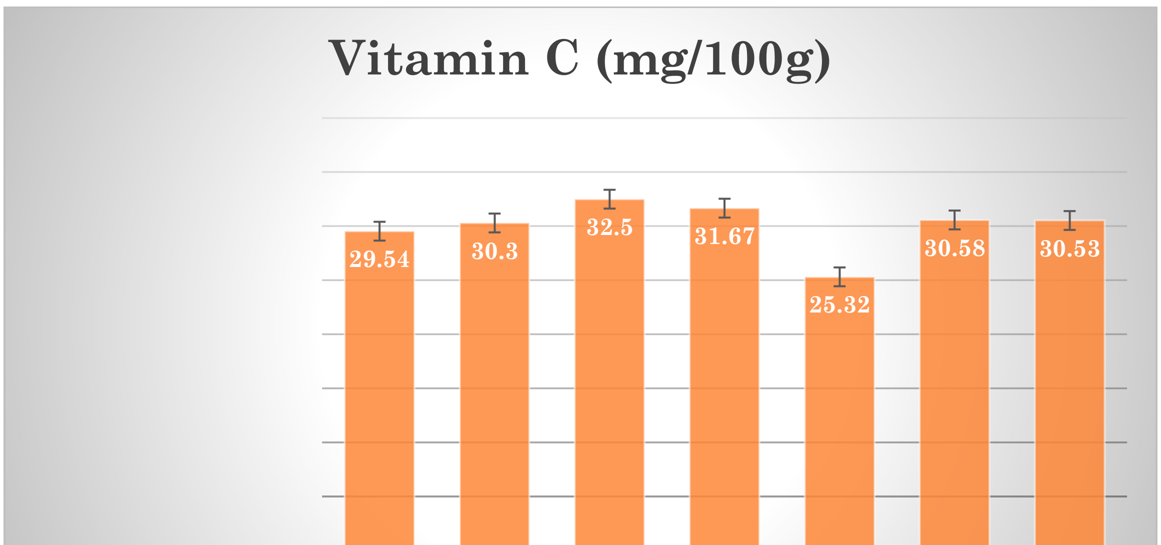
and ginger play a significant role in enhancing the flavonoid contents of the spiced tamarind samples, DPPH activity also followed a similar trend. And this suggests that clove and ginger in formulating the spiced tamarind paste contributed to the overall antioxidant capacity of the spiced paste. Phenolic compounds are well-known antioxidants (Biswas *et al*., 2023), and in this case, clove and ginger may be responsible for the increased phenolic content in the sample. High phenolic content in tamarind paste with highest percentage of cloves is in line with the research of (Gupta, 2013) that reported order of performance for total phenolic content observed in spices was highest in cloves. The lowest total phenolic content in the pure tamarind paste (100% Tamarind) emphasizes the importance of the other ingredients in enhancing the phenolic content. Vitamin C contents of the tamarind paste samples are shown in Figure3.There were significant differences in Vitamin C contents among the tamarind paste samples in this study. Vitamin C contents ranged from 25.32 to 32.5 mg/100g (Figure 3), and Sample BW (83.5% Tamarind, 6.5% Clove, and 10% Ginger) had the highest vitamin C content while tamarind paste Sample FR (100% Tamarind, 0% Clove, and 0% Ginger) had the lowest vitamin C content. It was observed that ginger contributed significantly to the vitamin C content of the tamarind paste. This is also in line with (Chan *et al* et al., 2011) that reported that ginger is a good source of Vitamin C and its presence in the spiced tamarind paste enhanced its vitamin C contents.



	IX	CR	BW	EU	FR	AB	DT
Vitamin C (mg/100g)	29.54	30.3	32.5	31.67	25.32	30.58	30.53

Figure 3: Vitamin C contents of ginger and clove spiced tamarind pastes

Key:
IX = 85.5% Tamarind, 6.5% Clove, 8% Ginger, CR = 88% Tamarind, 10% Clove, 2% Ginger
BW = 83.5% Tamarind, 6.5% Clove, 10% Ginger, DT = 91% Tamarind, 3% Clove, 6% Ginger
EU = 95% Tamarind, 3% Clove, 2% Ginger, AB = 87.5% Tamarind, 6.5% Clove, 6% Ginger
FR = 100% Tamarind, 0% Clove, 0% Ginger

Solubility and Sensory Attributes of Spiced Tamarind Paste

The consistent increase in solubility with rising temperatures aligns with well-established principles in solubility science. Higher temperatures generally lead to higher solubility as they provide the energy necessary to break intermolecular forces and facilitate the dissolution of solute particles (Cheremisinoff and Davletshina, 2013). This is a fundamental process in food science, where solubility affects the extraction of flavors, colors, and other essential compounds (Reyes-Jurado *et al* ., 2015). Therefore, the temperature-dependent behavior of tamarind paste solubility is consistent with established scientific knowledge. At 40°C, tamarind paste with highest percentage of ginger had lowest solubility while tamarind paste with zero ginger has the highest solubility. This confirms the temperature-dependent behavior on solubility of organic compounds, as the temperature increases the solubility increases in the spiced tamarind samples.

However, at 100°C, solubility was high in the non-spiced tamarind paste (100% tamarind) and tamarind paste with 2% ginger and 3%clove, but there was no significant difference in solubility among spiced tamarind samples as the levels of ginger and clove increased (Table 4). Ingredients such as ginger and clove may introduce compounds that influence solubility, which can vary with temperature and composition. The ability to control solubility by adjusting mixing ratios is valuable for chefs and food manufacturers seeking to optimize flavor release and infusion in their dishes. Ingredients that dissolve readily, as indicated by higher solubility, contribute to the rapid release of flavors, enhancing the overall sensory properties of the final product (Chen *et al*., 2023).
Samples with high percentage of ginger were the most preferred samples by the panelists in terms of flavor, taste and mouth feel. Ginger contains bioactive ingredients such as shogaols, zingerones and gingerols which have therapeutic effect and usually enhance flavor and aroma of foods (Laelago et al., 2023).

Conclusion

Spicing of tamarind paste with ginger and clove enhanced the anti-oxidative potential of the spiced tamarind paste. It increased significantly the Total flavonoids, Total phenolic and Total antioxidant capacity of the spiced tamarind paste. Inclusion of ginger and clove in tamarind also improved its sensory attributes and further broadens the utilization of tamarind. Tamarind Paste with 10% ginger had the highest sensory scores and was most preferred by the panelists.

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Conflict of interests
The authors declare no potential conflicts of interest.

Author contributions
Conceptualization: Sani M, Raji AO. Methodology: Sani M, Raji AO. Formal analysis: Aruna TE. Validation: Sani M, Raji AO. Data curation: Sani M, Raji AO. Writing - original draft: Sani M, Raji AO. Writing - review & editing: Raji AO, Aruna TE.

Ethics approval
This research was approved by the ethical committee of the Kwara State University, Malete, Kwara State (Ethical approval number KWASU/CR&D/REA/2024/0082 dated 07/10/2024).

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