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Formulation and Characterization of a Novel Carrot-based Sandwich Spread

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Abstract

Background: A necessity for developing vegetable-based sandwich spreads has arisen due to the growing number of vegans and the high cost of non-vegan spreads. Thus, the current study aimed to formulate and characterize a carrot-based sandwich spread, in terms of sensory and physicochemical properties.

Methods: Carrot-based sandwich spreads were developed, incorporating a spice mixture, white sauce, garlic paste, and mayonnaise, according to the results of sensory analysis. The variation of the color attributes and pH with time was investigated using a handheld colorimeter and benchtop pH meter, respectively. Shelf-life of the spreads was evaluated using the plate count method. Proximate analysis was carried out using AOAC methods. Sensory data were analysed using the Friedman test, while parametric data were analyzed using Analysis of Variance (ANOVA).

Results: Carrot-based sandwich spreads incorporated with spices, garlic paste, and white sauce exhibited the highest scores for the sensory attributes evaluated in this study. As expected, the physicochemical properties, especially colour, showed significant differences among the different formulations ($P<0.05$). The addition of chemical preservatives – potassium sorbate or sodium benzoate - showed no effect on the pH or colour of the best sandwich spreads and their temporal variation. Further, the shelf-life of the spreads increased to approximately 7 days under refrigerating conditions due to the addition of chemical preservatives.

Conclusions: The addition of spices, garlic paste, and white sauce resulted in the most preferred carrot-based sandwich spread. Additional steps need to be taken for colour preservation and increasing the microbial safety for extending the shelf-life.

Keywords: Carrot, Physicochemical Properties, Proximate Composition, Sandwich Spread, Sensory Properties

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INTRODUCTION

Ready-to-serve convenience foods have secured high demand globally mainly due to the socio-economic changes that have taken place over the last decades. Among the numerous convenience foods in the market, sandwich spreads stand out, since sandwiches are the main food that constitutes the diet of millions of people worldwide. In fact, An *et al.* (2016) reported that "approximately 53.2% of US adults consumed sandwiches on any given day" during the period 2003 – 2012 [1]. Further, the authors revealed that sandwich consumption provided about a quarter of the daily calorie intake and one-third of the fat intake [1-2]. The most popular sandwich spreads are jams, jellies, marmalades, butter, margarine, and cheese spreads that are of either high sugar or fat content [2]. In order to develop healthier spreads, research on meat-based and vegetable-based sandwich spreads has been carried out to a reasonable extent [3-5]. Reports on vegetable-based spreads such as carrot-based spreads are, however, scanty.

Carrot (*Daucus carota* L.) is a root vegetable belonging to the family Apiaceae. Apart from being a rich source of carbohydrates, carrot is a good source of minerals including Fe, Ca, Mg, and P. Further, this vegetable possesses numerous bioactive compounds including β-carotene with provitamin A activity, ascorbic acid, tocopherol, and anthocyanins [6]. Due to these active ingredients, carrot imparts numerous health benefits such as cancer inhibition, muscular degeneration prevention, decreased cataract formation, and cardiovascular disease prevention [6]. Further, the fiber content of raw carrots is approximately 2.8 g in 100 g [7-8]. Consumption of fiber leads to possible health effects such as the prevention or risk reduction of certain types of cancers, prevention of constipation, regulation of blood glucose levels, and shielding against heart disease [9]. Hence, carrot not only function as the base of sandwich spreads, but also may impart nutritive and functional properties to the spreads.

The role of food additives is multifaceted. Among the numerous types of food additives, chemical preservatives have become indispensable in the food industry [10]. The chemical preservatives used in this study were potassium sorbate (PS) and sodium benzoate (SB), which possess antifungal and antibacterial activities. Instances where PS has increased the shelf-life of foods are many. For example, 0.1% of PS has extended the shelf-life of chocolate cake of pH 6 – 7 inoculated with the fungal species *Penicillium citrinum* for 45 days [11]. Further, cooked ground fish inoculated with *Staphylococcus aureus* has shown an increased lag time of bacterial growth with the addition of PS [12]. Moreover, combinations of PS and other preservatives have improved the microbial safety and other quality attributes of foods [13]. SB, like PS, has increased the shelf-life of numerous foods including bread, cake, carbonated beverages, and mayonnaise [14]. Moreover, blends of sodium benzoate with other preservatives have exhibited synergistic antimicrobial potentials [15].

The aim of this study was to develop and evaluate the time-dependent variation of the quality of carrot-based sandwich spreads. Thus, carrot-based sandwich spreads were developed following sensory analysis. The physicochemical properties and microbial quality of the spreads were evaluated for 14 days thereby determining the shelf-life of the spreads. Also, the proximate composition of the spreads was analyzed. Directions for further improvements are finally given.

METHODOLOGY

Materials

Carrot (*Daucus carota* var. New Kuroda), corn flour, gelatin, mustard, salt, pepper, turmeric, sugar, butter, wheat flour, fresh milk, garlic, chilli flakes, coconut oil, eggs, lime juice, vinegar, curry leaves, potassium sorbate and sodium benzoate were purchased from a local retail shop. Fresh milk was pasteurized before use. Curry leaves were dried at 50 – 60 °C for

4 – 5 h in a commercial dehydrator before use.

Experiment 1: Selection of the Best Sandwich Spread Base

A sandwich base was prepared using carrot. Fixed quantities of carrot pulp (60 g) and water (100 mL) were used. For the carrot-based sandwich spread, the three different gelatin-corn flour masses used were 3 g – 4 g (C1), 3.5 g – 3.5 g (C2) and 4 g – 3 g (C3). The mixture was then cooked at 60 °C for 10 min. The resulting carrot spreads were then filled into sterilized glass jars and cooled before storing in the refrigerator.

Experiment 2: Selection of the Best Combination of Spices, Sugar, and Salt

Three combinations of mustard (M), pepper (P), sugar (SR), and salt (ST) were added to the best sandwich base selected from Experiment 1. For the carrot-based spread, the combinations (M-P) used were 0.3 g – 0.3 g (C4), 0.5 g – 0.3 g (C5) and 0.3 g – 0.5 g (C6). The quantities of sugar and salt added were 0.3 g and 2 g, respectively. The best carrot-based sandwich spread was selected via sensory analysis.

Experiment 3: Selection of the Best White Sauce Level

Three different quantities of white sauce were added to the best sandwich spreads selected from Experiment 2. The white source was formulated using butter (30 g), wheat flour (30 g), fresh milk (240 mL), salt (1.8 g) and pepper (0.5 g). The quantities of white sauce added to the carrot-based sandwich spread (60 g of carrot pulp) were 15 g (C7), 20 g (C8) and 25 g (C9). The best sandwich spread was selected via sensory analysis.

Experiment 4: Selection of the Best Garlic Paste Level

Under Experiment 4, three different quantities of garlic paste were added to the best sample identified from Experiment 3. The garlic paste was prepared using garlic paste (70 g), sugar (3 g), salt (3 g), curry leaves powder (5 g), chilli flakes (5 g), and vegetable oil (30 mL). The quantities of garlic paste added to the carrot-based sandwich spread were 1 g (C10), 3 g (C11) and 5g (C12). The best sandwich spread was selected via a sensory analysis.

Experiment 5: Selection of the Best Mayonnaise Level

The best garlic paste level selected from Experiment 4 was added to the best sandwich spreads from Experiment 2 to which three different quantities of mayonnaise were added. Mayonnaise was prepared using egg yolk (1), egg white (2), vinegar (1.5 tbsp), vegetable oil (250 mL), lime juice (1 tsp), salt (¼ tsp), pepper (½ tsp), mustard (¼ tsp), sugar (½ tsp) (tbsp: tablespoon; tsp: teaspoon). The quantities of mayonnaise added to the carrot-based sandwich spread were 10 g (C13), 15 g (C14) and 20 g (C15). The best sandwich spread was selected via a sensory analysis.

Experiment 6: Selection of the Best Sandwich Spread

The carrot-based sandwich spreads used for the determination of the best sandwich spread were the spreads selected from Experiments 2-5 and the control (CC) which was boiled carrot slices. The best carrot-based sandwich spread was selected using sensory analysis.

Sensory Evaluation

The best sandwich spreads selected from the above experiments (Experiments 2 to 5) were subjected to a sensory analysis to identify the best sandwich spread, while boiled carrot slices were used as the control. The sensory attributes considered were appearance, color, density, mouthfeel, texture, taste, aroma, flavor, and overall quality. Purchasing intention was also considered. A semi-trained panel of 30 panelists was used in the sensory evaluation. A five-point hedonic scale ranging from 5: like extremely to 1: dislike extremely was used during the assessment.

Determination of pH

The pH value of the sandwich spreads was tested using a benchtop pH meter (BP3001, Trans Instruments). The best carrot-based spreads selected from Experiments 2-5 were

tested for pH. Further, the pH of the final product that contained no artificial preservatives, and the final product with added potassium sorbate (PS) and added sodium benzoate (SB) were tested for 14 days with 7-day intervals. Let the carrot-based spread with added PS be C-PS, and that with added SB be C-SB.

Determination of Colour

The colour of the sandwich spreads was tested using a handheld colorimeter (PCE-CSM4, PCE Instruments). The best carrot-based spreads selected from Experiments 2-5 were tested for colour. In addition, the colour of the final products, C-PS and C-SB, was measured for 14 days with 7-day intervals.

Microbial Count

The best sandwich spreads selected from Experiment 6 were subjected to a microbial analysis, with and without chemical preservatives. Microbial analyses were carried out twice at 7-day intervals, using the tenfold serial dilution method according to the procedure described by Maturin and Peeler in the Bacteriological Analytical Manual Online (BAM) [16]. Three replicates from each treatment were used for the analysis. The growth medium used for the yeast and mold count was Potato Dextrose Agar and that used for the bacterial count was Nutrient Agar. The plates were incubated at 37 °C in the incubator. The colony count was taken from a Quebec Dark Field Colony Counter.

Proximate Analysis

Proximate analysis was carried out for the best products selected from Experiment 6. The percentages of moisture, ash, fat, and protein were analyzed using the AOAC (2010) methods [17]. Briefly, the moisture and ash contents were determined using gravimetric methods, the fat content was determined using the Soxhlet method, and the protein content was determined using the Kjeldahl method. Meanwhile, the reducing sugar content was determined using a titrimetric method [18]. The carbohydrate content was calculated as described by Diddana *et al*. (2021) [19].

Statistical Analysis

Data from sensory evaluations were analyzed using the Friedman Test, while quantitative data (physicochemical data) were analyzed using the Analysis of Variance (ANOVA). The Minitab (version 20) was used for the statistical analysis.

RESULTS AND DISCUSSION

Experiment 1: Selection of the Best Sandwich Spread Base

There was a significant difference ($P<0.05$) among the three carrot-based sandwich spreads for all sensory attributes except appearance and aroma. C1 (carrot paste 60 g, gelatin 3 g, corn flour 4 g) showed the highest mean ranks for all the sensory attributes. Therefore, C1 was selected for further analysis. These results suggested that the best gelatin and corn flour quantities are 3 g and 4 g, respectively for the preparation of a sandwich spread using carrot as the base (60 g). The mean scores for the sensory attributes are shown in Table 1.

Experiment 2: Selection of the Best Combination of Spices, Sugar, and Salt

All sensory attributes of the three carrot-based sandwich spreads were not significantly different ($P<0.05$) at 95% confidence level. The mean scores for the sensory attributes considered in this experiment are shown in Table 2. C5 (M – 0.5 g, P – 0.3 g, SR – 0.3 g, ST 2 g) showed the highest mean rank for the overall quality in addition to texture, mouthfeel, and flavor. Therefore, C5 was selected for further analysis. These results indicate that mustard (0.5 g) and pepper (0.3 g) are ideal in sandwich spreads with carrot as the base (60 g of pulp).

Experiment 3: Selection of the Best White Sauce Level

There was a significant difference ($P>0.05$) among the three carrot-based sandwich spreads for flavor and overall quality. Table 3

Table 1: Mean Scores for the Sensory Attributes of Sandwich Spreads (Experiment 1)

Sensory Attribute	Sandwich Spread			P
	C1	C2	C3	
Spreadability	4.367 ± 0.122	3.500 ± 0.171	3.800 ± 0.139	0.000
Texture	4.100 ± 0.100	3.700 ± 0.128	3.967 ± 0.131	0.026
Appearance	4.333 ± 0.088	4.133 ± 0.124	4.033 ± 0.112	0.059
Colour	4.533 ± 0.104	4.233 ± 0.164	4.167 ± 0.157	0.020
Aroma	3.533 ± 0.150	3.300 ± 0.119	3.333 ± 0.130	0.166
Density	4.100 ± 0.121	3.733 ± 0.143	3.500 ± 0.115	0.007
Overall quality	4.367 ± 0.102	3.800 ± 0.121	3.600 ± 0.123	0.001

Note: *Values are expressed as mean ± SE. Gelatin-corn flour masses: 3 g – 4 g (C1), 3.5 g – 3.5 g (C2) and 4 g – 3 g (C3) in 100 mL*

Table 2: Mean Scores for the Sensory Attributes of Sandwich Spreads (Experiment 2)

Sensory Attribute	Sandwich Spread			P
	C4	C5	C6	
Texture	3.667 ± 0.154	3.733 ± 0.197	3.700 ± 0.160	0.909
Appearance	3.867 ± 0.142	3.833 ± 0.167	3.767 ± 0.171	0.808
Colour	4.033 ± 0.140	3.967 ± 0.162	3.900 ± 0.154	0.662
Aroma	3.500 ± 0.157	3.300 ± 0.187	3.433 ± 0.164	0.640
Density	3.567 ± 0.149	3.500 ± 0.164	3.500 ± 0.178	0.732
Mouthfeel	3.600 ± 0.156	3.667 ± 0.200	3.433 ± 0.141	0.912
Flavour	3.567 ± 0.124	3.600 ± 0.189	3.600 ± 0.141	0.065
Overall quality	3.567 ± 0.164	3.733 ± 0.197	3.500 ± 0.150	0.868

Note: *Values are expressed as mean ± SE. Mustard and pepper masses for 60 g of pulp: 0.3 g – 0.3 g (C4), 0.5 g – 0.3 g (C5) and 0.3 g – 0.5 g (C6).*

Table 3: Mean Scores for the Sensory Attributes of Sandwich Spreads (Experiment 3)

Sensory Attribute	Sandwich Spread			P
	C7	C8	C9	
Texture	3.600 ± 0.177	3.867 ± 0.164	3.667 ± 0.111	0.382
Appearance	3.467 ± 0.184	3.833 ± 0.160	3.500 ± 0.171	0.147
Colour	3.667 ± 0.205	3.867 ± 0.196	3.867 ± 0.202	0.528
Aroma	3.467 ± 0.171	3.567 ± 0.164	3.867 ± 0.171	0.133
Density	3.567 ±0.171	3.933 ± 0.151	3.733 ± 0.159	0.064
Mouthfeel	3.400 ± 0.177	3.767 ± 0.164	3.800 ± 0.151	0.073
Taste	3.433 ± 0.157	3.833 ± 0.160	3.700 ± 0.119	0.168
Flavour	3.367 ± 0.206	3.767 ± 0.164	3.867 ± 0.164	0.043
Overall quality	3.300 ± 0.167	3.767 ± 0.177	3.967 ± 0.131	0.054

Note: *Values are expressed as mean ± SE. White source masses for 60 g of pulp: 15 g (C7), 20 g (C8) and 25 g (C9).*

shows the mean scores for the sensory attributes considered in this experiment. The C9 (white sauce 25 g) treatment showed the highest mean rank for flavour, and overall acceptability. Thus, C9 was selected for further analysis. These results show that incorporating 25 g of white sauce for 60 g of carrot pulp presents favourable sensory attributes to sandwich spreads.

Experiment 4: Selection of the Best Garlic Paste Level

There was a significant difference (P>0.05) among the three carrot-based sandwich spreads for all attributes. The mean scores for the sensory attributes considered in this study are shown in Table 4. Since C11 (garlic paste 3 g) showed the highest mean score for all the attributes, it was selected for further analysis.

Experiment 5: Selection of the Best Mayonnaise Level

Significant differences (P<0.05) were observed among the three carrot-based sandwich spreads for all the sensory attributes (Table 5). C14 (mayonnaise 15 g), which showed the highest mean ranks for all the sensory attributes was selected for the final sensory evaluation. These results indicate that the addition of 15 g of mayonnaise tend to elevate the flavour of sandwich spreads.

Table 4: Mean Scores for the Sensory Attributes of Sandwich Spreads (Experiment 4)

Sensory Attribute	Sandwich Spread			P
	C10	C11	C12	
Texture	3.467 ± 0.142	4.333 ± 0.138	3.400 ± 0.123	0.000
Appearance	3.400 ± 0.149	4.667 ± 0.088	3.433 ± 0.141	0.000
Colour	3.200 ± 0.162	4.333 ± 0.121	3.500 ± 0.115	0.000
Aroma	3.400 ± 0.113	4.300 ± 0.128	3.200 ± 0.176	0.000
Density	3.200 ± 0.139	4.167 ± 0.136	3.033 ± 0.148	0.000
Mouthfeel	3.267 ± 0.151	4.133 ± 0.124	3.400 ± 0.149	0.000
Taste	3.333 ± 0.111	4.333 ± 0.111	3.767 ± 0.141	0.000
Flavour	3.200 ± 0.121	4.367 ± 0.102	3.600 ± 0.132	0.000
Overall quality	3.267 ± 0.117	4.633 ± 0.090	3.367 ± 0.131	0.000

Note: *Values are expressed as mean ± SE. Garlic paste masses for 60 g of pulp: 1 g (C10), 3 g (C11) and 5 g (C12).*

Table 5: Mean Scores for the Sensory Attributes of Sandwich Spreads (Experiment 5)

Sensory Attribute	Sandwich Spread			P
	C13	C14	C15	
Texture	3.733 ± 0.135	4.333 ± 0.133	3.600 ± 0.141	0.001
Appearance	3.733 ± 0.143	4.333 ± 0.111	3.800 ± 0.162	0.002
Colour	4.033 ± 0.140	4.400 ± 0.103	3.800 ±0.155	0.021
Aroma	3.833 ± 0.145	4.167 ± 0.136	3.633 ± 0.155	0.059
Density	3.733 ± 0.179	4.100 ± 0.121	3.667 ± 0.146	0.011
Mouthfeel	3.667 ± 0.200	4.100 ± 0.121	3.633 ± 0.148	0.032
Taste	3.633 ± 0.155	4.300 ± 0.109	3.833 ± 0.160	0.023
Flavour	3.700 ± 0.180	4.367 ± 0.122	3.700 ± 0.174	0.005
Overall quality	3.500 ± 0.142	4.400 ± 0.091	3.500 ± 0.171	0.000

Note: *Values are expressed as mean ± SE. Mayonnaise masses for 60 g of pulp: 10 g (C13), 15 g (C14) and 20 g (C15).*

Experiment 6: Selection of the Best Carrot-Based Sandwich Spread

The final sensory evaluation was carried out using the control sample (CC) and the four best samples selected from Experiments 2-5 (i.e. C5, C9, C11, and C14). According to the Friedman analysis, there were significant differences ($P<0.05$) in sensory attributes among the five formulations (Figure 1). The sandwich spread produced under the C11 treatment showed the highest mean scores for all the sensory attributes considered in this study, namely appearance (4.300 ± 0.137), colour (4.367 ± 0.131), density (4.367 ± 0.140), mouthfeel (4.500 ± 0.104), texture (4.333 ± 0.138), taste (4.533 ± 0.124), aroma (4.233 ± 0.124), flavour (4.567 ± 0.092), and overall quality (4.633 ± 0.102); hence it was selected as the best carrot-based product. As expected, the mean rank of purchasing intention for C11 (4.733 ± 0.095) was significantly higher ($P<0.05$) than that for other carrot-based products (< 3.500).

pH and Colour of the Selected Sandwich Spreads

The mean pH values of the different sandwich spreads developed in this study are indicated in Table 6. The pH values of the different carrot-based sandwich spreads were significantly different from each other ($P<0.05$). However, the pH of the sandwich spreads was within the range of pH 5.5 - 5.8. These results indicate that the incorporation of white sauce, mayonnaise, or garlic paste alters the pH of the carrot-based sandwich spreads only within a narrow range.

The colour (lightness, redness, and yellowness) of the sandwich spreads is given in Table 1. As expected, the incorporation of white sauce resulted in a significant increase in the lightness of carrot-based sandwich spreads ($P<0.05$). According to sensory analysis, the colour of the white sauce-added sandwich spread with higher lightness was preferred over that of the mayonnaise-added sandwich spread. The redness and yellowness of the carrot-based sandwich spread decreased with the addition of white sauce (C11). In contrast, the redness and yellowness of the carrot-based sandwich remained the same with the incorporation of mayonnaise, as shown in Table 6. Nevertheless, C11 treatment, which contained spices, white sauce, and garlic paste, in addition to the base, was the most preferred sandwich spread concerning the colour.

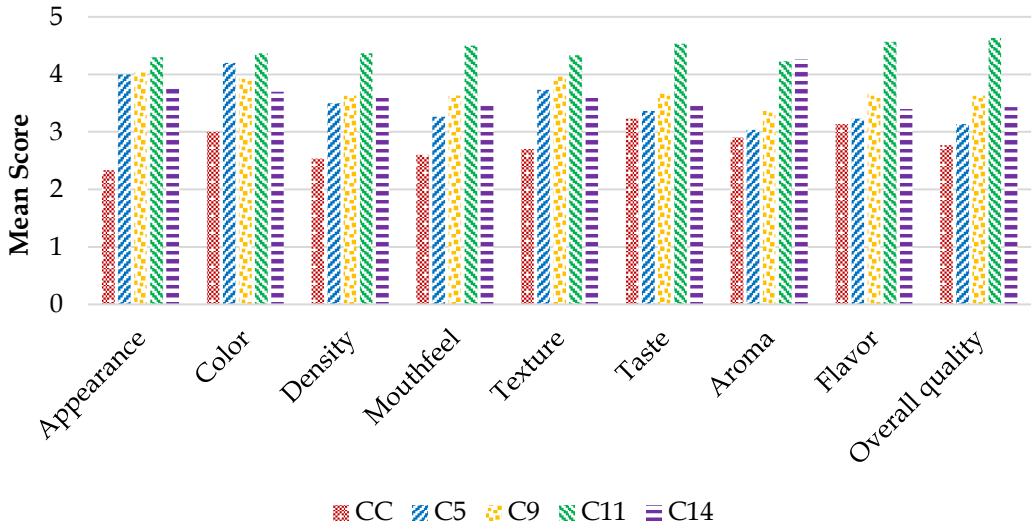

Figure 1: Mean Scores of Carrot-based Sandwich Spreads for Sensory Attributes

Note: *CC: boiled carrot slices, C5: sandwich spread with spices, C9: sandwich spread with spices and white sauce, C11: sandwich spread with spices, white sauce, and garlic paste, C14: sandwich spread with spices, mayonnaise, and garlic paste. Each sensory attribute of the five carrot spreads showed a significant difference ($P<0.05$).*

Table 6: Variation of pH and Colour Attributes among Sandwich Spreads

Sandwich Spread	pH	Colour Coordinates		
		L*(Lightness)	a*(Redness)	b*(Yellowness)
C5	$5.64^{b} \pm 0.06$	$20.42^{b} \pm 1.99$	$16.45^{a} \pm 2.00$	$105.92^{a} \pm 2.50$
C8	$5.83^{a} \pm 0.02$	$41.76^{a} \pm 3.74$	$7.28^{b} \pm 0.99$	$88.91^{b} \pm 1.57$
C11	$5.47^{c} \pm 0.01$	$40.99^{a} \pm 2.51$	$2.17^{b} \pm 0.99$	$49.07^{c} \pm 2.12$
C14	$5.47^{c} \pm 0.01$	$36.34^{a} \pm 3.00$	$15.57^{a} \pm 3.46$	$111.81^{a} \pm 7.64$

Note: *Values are expressed as mean ± SE. Means with the same letter superscripts within each column of each block are not significantly different at the 0.05 level. C: carrot-based sandwich spread, C5: with spices, C8: with spices and white sauce, C11: with spices, white sauce, and garlic paste, C14: with spices, mayonnaise, and garlic paste.*

Temporal Variation of pH and Colour of the Best Sandwich Spreads with or Without Preservatives

Variation of pH

Table 2 shows the variation of pH and colour of sandwich spreads stored in refrigerating conditions with time. The pH of the carrot-based sandwich spreads, i.e. the best carrot-based sandwich spread with no preservatives (C11), C11 incorporated with potassium sorbate (C11-PS) and C11 incorporated with sodium benzoate (C11-SB), decreased significantly with time ($P<0.05$). However, this variation occurred within a narrow range (pH 6.17 to 6.38). The regression equations revealed that the decrease of pH with time occurred gradually with different slopes. The regression equations for the variation of the pH of the three treatments with time (in days) are as follows.

C11 : $pH = 6.3583 - 0.0145\ Time$ (Adjusted $R^2 = 85.26\%$)

C11-PS : $pH = 6.3606 - 0.0064\ Time$ (Adjusted $R^2 = 95.72\%$)

C11-SB : $pH = 6.3639 - 0.0079\ Time$ (Adjusted $R^2 = 94.38\%$)

As expected, there was no significant difference ($P>0.05$) in the pH of the potassium sorbate and sodium benzoate added sandwich spreads. However, those pH values were lower than that of C11. The mean pH values of the treatments over the 14-day period were close and were as follows: C11: pH 6.18 ± 0.00, C11-PS: pH 6.27 ± 0.01, and C11-SB: pH 6.26 ± 0.01.

Variation of Colour with Time

The variation of colour of the most preferred carrot-based spreads, with or without preservatives, is shown in Table 7. The lightness of the three carrot-based sandwich spreads was not significantly different ($P=0.972$). However, the lightness decreased significantly in the first seven days, after which it increased to a value higher than the original value ($P<0.001$). This experiment revealed that the incorporation of the preservatives (i.e. PS and SB) has no effect on the lightness of the sandwich spreads and the variation of the lightness of the sandwich spreads with time.

The redness of the three carrot-based sandwich spreads was not significantly different ($P>0.05$) and increased significantly with time ($P<0.001$). The results revealed that the incorporation of the preservatives (i.e. PS and SB) had no effect on the redness of the sandwich spreads and the variation of the redness of the sandwich spreads with time. Similar to the lightness and redness, the yellowness of the three carrot-based sandwich spreads also did not differ significantly ($P<0.05$). The yellowness increased in the first week, after which it decreased partially ($P<0.001$). In fact, the yellowness decreased in the first week after which it increased sharply to a value higher than the original one. These results reveal that the incorporation of the preservatives (i.e. PS and SB) has no effect on the yellowness of the sandwich spreads and the variation of the yellowness with time.

Table 7: Variation of pH and Colour of the Best Sandwich Spreads with Time

Sandwich Spread	Time (Days)	pH	Colour Coordinates		
			L* (Lightness)	a* (Redness)	b* (Yellowness)
C11	0	$6.38^{a} \pm 0.01$	$40.92^{b} \pm 2.58$	$3.80^{b} \pm 1.49$	$48.60^{c} \pm 2.06$
	7	$6.21^{b} \pm 0.01$	$30.62^{b} \pm 1.98$	$8.37^{b} \pm 1.59$	$94.99^{a} \pm 2.23$
	14	$6.17^{c} \pm 0.00$	$52.66^{a} \pm 7.11$	$22.23^{a} \pm 3.75$	$73.06^{b} \pm 5.27$
C11-PS	0	$6.36^{a} \pm 0.01$	$47.25^{a} \pm 4.13$	$3.37^{b} \pm 1.88$	$46.37^{c} \pm 4.08$
	7	$6.31^{b} \pm 0.00$	$29.17^{b} \pm 4.51$	$8.08^{b} \pm 1.65$	$100.58^{a} \pm 4.98$
	14	6.27c ± 0.01	$50.22^{a} \pm 4.37$	$31.56^{a} \pm 3.70$	$85.82^{b} \pm 5.00$
C11-SB	0	$6.36^{a} \pm 0.01$	$41.00^{ab} \pm 8.00$	$4.26^{c} \pm 2.06$	$43.86^{c} \pm 6.71$
	7	$6.30^{b} \pm 0.00$	$30.69^{b} \pm 2.02$	$12.16^{b} \pm 3.27$	$100.43^{a} \pm 2.49$
	14	$6.25^{c} \pm 0.01$	$51.57^{a} \pm 2.96$	$21.50^{a} \pm 3.46$	$71.36^{b} \pm 7.00$

Note: *Values are expressed as mean ± SE. The means with the same letter superscripts within each column of each block are not significantly different at the 0.05 level. C11: Carrot-based sandwich spread with spices, white sauce, and garlic paste, PS: Potassium sorbate, SB: Sodium benzoate*

Concisely, the addition of food preservatives – potassium sorbate or sodium benzoate – at a concentration of 0.1% (w/w) had no effect on the color and on the time-dependent color variation of carrot-based sandwich spreads.

Shelf-life of Sandwich Spreads: Microbial Analysis

The sandwich spreads developed in this study were not heat treated to minimize the deterioration of heat-sensitive compounds in carrot or beetroot. Instead, permitted levels (i.e. 0.1% w/w) of potassium sorbate or sodium benzoate were used. Microbial analysis was conducted based on the total plate count and yeast and mold count of the sandwich spreads stored at refrigerating temperature for 14 days.

There was a microbial colony growth within the first week in C11, which had no preservatives. Meanwhile, no microbial colony growth was observed in preservative-added samples (C11-PS, C11-SB) after 7 days. However, bacteria, and yeast and mold overgrowth were observed by day 14. These results indicated the development of a lag phase of microbial growth due to the incorporation of the preservatives PS and SB. The spread with no preservatives had a relatively shorter shelf life than the preservative-added ones. The shelf life of the spreads with no preservatives may be only a few days, while that of the spreads with preservatives may be approximately 7 days. These results highlight the need for heat processing of the sandwich spreads despite the damage it might cause to heat-sensitive compounds.

Proximate Composition

The proximate composition of the best carrot-based sandwich spread (C11) is given in Table 8.

Table 8: Proximate Composition of the Best Sandwich Spread

Food Constituent	Quantity (w/w %)
	Carrot-based Sandwich Spread (C11)
Moisture	87.8
Ash	1.6
Fat	1.9
Protein	1.6
Reducing sugars	1.8
Total carbohydrate	7.1

Note: *C11: The best carrot-based sandwich*

Favourably, the carrot-based sandwich spread developed in this study contained significantly lower fat and sugar contents than other sandwich spreads such as butter, cream cheese, or jam [20-22]. Hence, the carrot-based sandwich spread developed in this study can be identified as a healthier spread.

CONCLUSIONS

This study highlights an opportunity to increase the sensory attributes of carrot-based sandwich spreads by incorporating spices, garlic paste, white sauce, or mayonnaise. The incorporation of spices, garlic paste, and white sauce in carrot-based sandwich spreads enhanced the sensory properties of the spreads, which substantially led to higher purchasing intention of the product. Although it was expected that the addition of chemical preservatives, i.e. potassium sorbate or sodium benzoate, may lead to a substantial increase in the shelf-life, the addition of preservatives was ineffective in maintaining the physicochemical properties of the sandwich spreads.

However, the shelf-life of the sandwich spreads increased as a result of the addition of chemical preservatives to the sandwich spreads according to the results of microbial analysis. Specifically, a lag phase in the growth of microbes, which may be enhanced by incorporating blends of antimicrobial agents, was observed due to the addition of potassium sorbate and sodium benzoate. As the sugar and fat contents of the carrot-based sandwich spreads are significantly lower than those of commonly used sandwich spreads, the carrot-based sandwich spread developed in this study can be called a 'healthy spread'.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTIONS

IW: Investigation, Data curation, Analysis of data. GP: Conceptualization, Analysis of data, Writing the manuscript, and Supervision. MA: Investigation, Data curation, Analysis of data.

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REFERENCES

1 An R, Andrade F, Grigsby-Toussaint D. Sandwich consumption in relation to daily dietary intake and diet quality among US adults, 2003–2012. Public Health. 2016; 140:206-212.
2 Hubbard KL, Must A, Eliasziw M, Folta SC, Goldberg J. What's in children's backpacks: Foods brought from home. Journal of the Academy of Nutrition and Dietetics. 2014; 114(9):1424-31.
3 Patel AA, Gupta SK. Studies on a soy-based low-fat spread. Journal of Food Science. 1988; 53(2):455-459.
4 Sreelakshmi KR, Manjusha L, Nagalakshmi K, Chouksey MK, Venkateshwarlu G. Ready-to-serve crab sandwich spread in retort pouch: Product development and process optimization. Journal of Aquatic Food Product Technology. 2015; 24(4):315-329.
5 Pandey A, Keshri RC, Kumar Y. Development and quality assessment of pork sandwich spead incorporated with different levels of antioxidant mixture (BHA and BHT) during frozen storage (−18±1° C). Nutrition & Food Science. 2016.
6 Sharma KD, Karki S, Thakur NS, Attri S. Chemical composition, functional properties and processing of carrot—a review. Journal of Food Science and Technology. 2012; 49(1):22-32.
7 Amounts of fiber in beets. Retrieved from https://www.dietandfitnesstoday.com/fiber-in-beets.php. on 29 June 2022.
8 Amounts of fiber in carrots. Retrieved from https://www.dietandfitnesstoday.com /fiber-in-carrots.php. on 29 June 2022.

9 Chhikara N, Kushwaha K, Sharma P, Gat Y, Panghal A. Bioactive compounds of beetroot and utilization in food processing industry: A critical review. Food Chemistry. 2019; 272:192-200.

10 Karunaratne DN, Pamunuwa GK. Introductory Chapter: Introduction to food additives. InFood Additives 2017. IntechOpen.

11 Morassi LL, Silva BS, Furtado MM, Freire L, Santos JL, Chaves RD, Granato D, Silva MP, Peña WE, Sant'Ana AS. Growth/no-growth modeling to control the spoilage of chocolate cake by *Penicillium citrinum* LMQA_053: Impact of pH, water activity, temperature, and different concentrations of calcium propionate and potassium sorbate. Food Control. 2022; 139:109064.

12 Tango CN, Khan I, Park YS, Oh DH. Growth of *Staphylococcus aureus* in cooked ready-to-eat ground fish as affected by inoculum size and potassium sorbate as food preservative. LWT-Food Science and Technology. 2016; 71:400-8.

13 Wang C, Yang J, Zhu X, Lu Y, Xue Y, Lu Z. Effects of Salmonella bacteriophage, nisin and potassium sorbate and their combination on safety and shelf life of fresh chilled pork. Food Control. 2017; 73:869-877.

14 Chaleshtori FS, Arian A, Chaleshtori RS. Assessment of sodium benzoate and potassium sorbate preservatives in some products in Kashan, Iran with estimation of human health risk. Food and Chemical Toxicology. 2018; 120:634-638.

15 Stanojevic D, Comic L, Stefanovic O, Solujic-Sukdolak S. Antimicrobial effects of sodium benzoate, sodium nitrite and potassium sorbate and their synergistic action in vitro. Bulgarian Journal of Agricultural Science. 2009; 15(4):307-311.

16 Bacteriological Analytical Manual (BAM), US Food and Drug Administration. Retrieved from https://www.fda.gov/food/laboratory-methods-food/bacteriological-analytical-manual-bam on 01 October 2022.

17 AOAC - Association of Official Analytical Chemists International. 2010. Official methods of Analysis, 19th edn. Association of Official Analytical Chemists, Washington, DC. pp. 3653.

18 Egan H, Kirk RS, Sawyer R, Pearson D. Pearson's chemical analysis of foods. (No Title). 1981.

19 Diddana TZ, Kelkay GN, Tescha EE. Nutritional composition and sensory acceptability of stinging nettle (Urtica simensis) flour-supplemented unleavened maize (Zea mays L.) flatbread (Kitta). International Journal of Food Science. 2021; 2021:1-1.

20 Brighenti M, Govindasamy-Lucey S, Lim K, Nelson K, Lucey JA. Characterization of the rheological, textural, and sensory properties of samples of commercial US cream cheese with different fat contents. Journal of Dairy Science. 2008; 91(12):4501-4517. https://doi.org/10.3168/jds.2008-1322.

21 Vidanagamage SA, Pathiraje PM, Perera OD. Effects of cinnamon (*Cinnamomum verum*) extract on functional properties of butter. Procedia Food Science. 2016; 6:136-142.

22 Akinlolu-Ojo T, Nwanna EE, Badejo AA. Physicochemical constituents and anti-oxidative properties of ripening hog plum (*Spondias mombin*) fruits and the quality attributes of jam produced from the fruits. Measurement: Food. 2022; 7:100037.