Journal of Agriculture and Food Research 12 (2023) 100540

Contents lists available at ScienceDirect

Journal of Agriculture and Food Research

journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

Quality evaluation of orange-fleshed sweet potato-pineapple blended jam

Newlove A. Afoakwah [a,*], Francis K. Amagloh [a], Gustav K. Mahunu [a], Shaheeda Wireduaa Ayyub [a], William Tchabo [b], Patrick Owusu-Ansah [a]

[a] Department of Food Science and Technology, Faculty of Agriculture, Food and Consumer Sciences, University for Development Studies, P. O. Box 1882, Tamale, Ghana
[b] Department of Food Science and Nutrition, National Advanced School of Agro-Industrial Sciences (ENSAI), University of Ngaoundere, Ngaoundere, Cameroon

A R T I C L E I N F O

Keywords:
Orange-fleshed sweet potato
Jam
Nutritional
Sensory
Microbiological quality

A B S T R A C T

This research aimed to develop a jam using orange-fleshed sweet potato puree (OFSPP) and pineapple pulp (PP) and to assess nutritional, gelling, sensory, and microbiological qualities. Four jam formulations of OFSPP: PP (70%:30, 50%:50%, and 30%:70) and 100% PP were developed and evaluated. Increasing the level of OFSPP resulted in a significant ($P<0.05$) decrease in moisture content (34.39–23.70%), but increased the fat (0.16–0.18%), ash (0.35–0.40%), protein (0.93–1.57%), and carbohydrates (61.70–67.69%) content. The concentration of β–carotene decreased with a reducing OFSPP fraction ($P<0.05$). After 12 weeks of storage, the 50% OFSPP and 50% pineapple jam had a total plate count of 4.50 CFU/g, although coliform and mould were not present in all the processed jam samples. The mixed jam with 50% OFSPP: 50% PP had a higher sensory acceptance. These results indicate that food processors could develop OFSP-PP jams as a β–carotene enriched functional food.

1. Introduction

Sweet potato (*Ipomoea batatas*, L.) is an American plant discovered in Africa in the 1500s [1]. The crop is widely grown in Africa and is recognized as drought-resistant and a food security crop with an annual yield of roughly 24.2 million tons [1]. Orange-Fleshed Sweet Potato (OFSP) is a bio-fortified sweet potato with β–carotene [2]. The OFSP has a characteristic sweet flavour and a pleasing yellow-to-orange appearance. In Sub-Saharan Africa, it is promoted as a food-based method to alleviate Vitamin A Deficiency [1]. Vitamins, minerals, non-digestible dietary fibre, polyphenols, antioxidants, and anthocyanin are abundant in sweet potatoes [2,3]. The roots of sweet potatoes also contain water-soluble pectin, making them a viable raw material for jams and jellies [4]. Additionally, consuming cooked pureed OFSP daily may benefit vitamin A reserves in populations at risk of deficiency [5].

OFSP has been used to refine existing recipes for bread, snack, confectionery products, and complementary foods [2,6]. Fresh OFSP roots are usually boiled, baked, roasted, or fried, and they are occasionally sliced to form chips or added to salads [1]. OFSP is currently in high demand due to its high level of carotene and non-provitamin carotenoids and its anti-carcinogenic and cardiovascular disease inhibitory properties [1,2,7,8]. Again, β-carotene increases humoral cell-mediated immunity and phagocytosis, inhibits lipid peroxidation regulates the formation and function of prostaglandins, thromboxanes, and leukotrienes [9]. As a result, diversifying the utilization of OFSP through recipe refinement could be effective strategy to assure the populace of the benefits of OFSP [1]. In this research, pineapple was used together with OFSP [4] to make jam.

The setting of jam depends on the presence of pectin [10]. However, commercial pectin, used in producing fruit preserves in Ghana, is highly expensive and its supply is limited. The high cost and limited supply of pectin have led to the search for other suitable and cheaper gelling agents in the production of jams [11]. Besides, pineapple is a tropical fruit preferred by consumers and has an abundance of bioactive compounds, aroma compounds, and nutrients [12], which may assure consumers of nutrient and health adequacy. Also, utilizing OFSP and pineapple in jam making may cause a drop in post-harvest losses associated with these seasonal crops [13]. Also, it may boost the income levels of farmers who are into the cultivation of these crops.

Pineapple (*Ananas comosus*) is a tropical and sub-tropical plant that belongs to the *Bromeliaceae* family and contains essential phytochemicals including carotene, bromelain, vitamins (A and C), minerals, and organic acid; also it is known to possess a variety of beneficial biological activities including anti-browning, anti-inflammatory and antiplatelet properties [10,12], for instance, bromelain present in the fruit promotes iron absorption and regulates blood pressure and heart rate [14]. More

* Corresponding author.
E-mail address: nafoakwah@uds.edu.gh (N.A. Afoakwah).

https://doi.org/10.1016/j.jafr.2023.100540
Received 3 December 2022; Received in revised form 21 February 2023; Accepted 23 February 2023
Available online 28 March 2023

so, Due to its high bromelain content, which aids in lipolysis and lessens the severity of cardiovascular syndromes, pineapple has evolved as a fruit that is beneficial in the treatment of obesity and dys-lipidemia [15]. Fresh fruits have a documented protective effect against cardiovascular disorders [15]. Illnesses including Type 2 diabetes, osteoarthritis, and cardiovascular conditions can all be attributed to obesity [15]. However, pineapple juice might fight obesity and has no negative side effects [15]. Treatment with a hydro-alcohol *Ananas comosus* extract reduced serum levels of total cholesterol, LDL cholesterol, and VLDL cholesterol, according to research [16]. In addition, pineapple reduced total cholesterol, triacylglycerol, and LDL-cholesterol in rats and mice, according to Ref. [16]. The result was attributed to bromelain's presence, which possesses lipolytic and proteolytic activity, and to the raw juice's high fibre content, which had a hypo-cholesterolemic impact [16]. The risk of lipid-related disorders may be reduced by pineapple [17]. It is important to note that pineapple includes a significant quantity of vitamin C, which is used in antioxidant-based therapies to combat the negative effects of obesity-related fat build-up [15]. Additionally, the anti-obesity action of pineapple juice may be attributed to the phenolic chemicals in pineapple [18]. In obese mice, gallic acid decreased serum triacylglycerol and body weight [19]. By controlling lipid metabolism, syringic acid has anti-obesity and anti-steatosis properties [20]. By modifying enzymatic, hormonal, and inflammatory responses, ferulic acid has been shown to reduce the risk obesity [21]. It has been suggested that pineapple may offer protection against the onset of insulin resistance brought on by obesity [16].

Jams are a widely accepted commodity, and the market for jam, jelly, and preserves is expanding at a faster rate [22]. The world's largest producer and consumer of jam is France [23]. About 3.36 billion tons of jams were consumed and around 4000 tons were manufactured in 2016 [Centre for the Promotion of Imports from Developing Countries (CBI) [24]. Jam production is particularly notable in Turkey, Spain, Chile, India, China, the United States, and Brazil [23]. In Brazil, 15.5 million tons of jam were produced in 2017 [25]. The jams prepared from strawberries, oranges, grapes, apricots, blueberries, mangoes, and pomegranates are the most popular and widely manufactured [26–28]. With around 485,000 tons of jams and fruit preserves produced each year, industrial production of jams and spreads in Europe is highly significant economically [28]. Additionally, Data Bridge Market Research's analyses showed that during the forecast period of 2022–2029, the global market for jam, jelly, and preserves expanded at a CAGR of 4.25% [29]. The market for jam, jelly, and preserves will increase at a faster rate due to the growing popularity of jams among young people [30]. Hence, this study aims to develop a jam using orange-fleshed sweet potato puree (OFSPP) and pineapple pulp (PP) and assess nutritional, gelling, sensory, and microbiological qualities.

2. Materials and methods

2.1. Sources of raw materials

OFSP roots [29] were purchased in Kushebu, Ghana's Northern Region, and carried in sacks to the Faculty of Agriculture, Food, and Consumer Sciences, Food Production Laboratory. The smooth cayenne pineapple and yellow lemon were purchased from a fruit trader in Tamale Municipality. Whiles the sugar was bought from a supermarket in Tamale Municipality. The roots of OFSP and the pineapple fruits were washed under running water and air-dried for 5 min. Clean, fresh, and undamaged OFSP roots (5400 g) were diced into an unvarying size of 2.50 cm with a sterile knife. The chopped roots were wet-cooked for 30 min after boiling using Delron: Model No.: DGS- 002AS stove with enough water that covered at least 1 inch of the OFSP; it was then allowed to cool for 5 min. The boiled OFSP roots were pureed (OFSPP) using a mashed potato equipment. The clean and undamaged pineapple fruits (8600 g) were peeled using a sterilized YKC hot chef stainless steel knife, then chopped into pieces and pulped (PP) with a mixer (Binatone: Model No.: BLG-402).

2.2. Jam processing

Based on preliminary research [31], the OFSPP and PP were mixed in proportions OFSPP: PP (70%:30, 50%:50%, and 30%:70) and 100% PP) using the classic method of jam making described by Ref. [14] with minor modifications, since sweet potato contains pectin [4], additional pectin was not added to the OFSPP and PP mixed jam, except for the 100% PP. The jams were processed in an open stainless-steel pan on a stove (Delron: Model No.: DGS- 002AS) for 30 min at 95 °C. The acidity was attuned to a pH of 3.0–3.2 by adding lemon juice of 0.3%. Sugar (15%) was added and the mixture was cooked to 64.56 to 65.40 °Brix. Afterwards, the jams were poured hot into 300-mL sterilized glass bottles (weighing 200 g) with metal covers and allowed to cool before being analysed.

2.3. Compositional analysis and the energy value of the formulated jams

The methods described in the Official Methods of Analysis of the Association of Official Analytical Chemists [32] were used to determine the amount of moisture (AOAC 925.10), crude protein (AOAC 960.52), and crude fat (AOAC 922.06) in all the jam formulations. Total dietary fibre was determined by the enzymatic-gravimetric method (AOAC 991.43), and carbohydrate content was calculated by adding protein, fat, moisture, ash, and total dietary fibre and subtracting it from 100% [33]. As indicated by Ref. [33], the energy content of the formulated jams was determined using the Atwater factor, where 4 = carbohydrate, 9 = fat, and 4 = protein.

2.4. β-Carotene and ascorbic acid determination

The determination of β-carotene was carried out using a UV/vis Spectrophotometer V-530 (Jasco, Madrid, Spain), according to the procedure reported by Ref. [34]. Five (5) grams of jam sample were weighed into a 50-mL centrifuge tube. It was allowed to stand for 15 min at 41 °C with intermittent shaking before vortexing for 15 min. Finally, the samples were centrifuged for 10 min at 1370 g. The recovered supernatant was transferred to a new test tube. The β-carotene was re-extracted with 5 mL acetone, then centrifuged using the same settings. The supernatants were mixed and then filtered through No. 42 Whatman filter paper. A UV/Vis spectrophotometer was used to measure the absorbance of the filtrate at a wavelength of 449 nm, while the 2, 6- dichlorophenol indophenol titration method was used to determine ascorbic acid [35].

2.5. pH and total soluble acids (°Brix)

A calibrated "Crison" pH meter was used to determine the pH of the jam at 4.01, 7.00, and 9.21. The pH meter electrodes were dipped into a 20 mL jam sample for 15 s, and the pH value was recorded. A Reichert hand refractometer (AR200TM) was used to record total soluble solids (°Brix), which was calibrated with distilled water. Using a pipette dropper, 2–3 drops of the sample were transferred to the refractometer prism. After that, the degree Brix was recorded.

2.6. The gel profile of the processed jam samples

Using a standard technique two outlined by Ref. [36], a Rapid Visco-Analyzer (RVA) (RVA Model 4500, Perten Instruments, Australia) was used to analyse the gelling characteristics of the processed jam. Briefly, a 23-min heating and cooling cycle were configured to hold the sample mixtures (3.5 g sample/25 g water) at 50 °C for 1 min, then heat to 95 °C for 5 min, then cool to 50 °C for 7.5 min, and hold for 1 min.

2.7. Microbial analysis

The jams were assessed after preserving at room temperature for 12 weeks, and the total plate count, yeast, mould counts, and total coliform counts were measured.

2.7.1. Total plate count

The total plate count was determined according to Ref. [33]. In brief, equipment for sampling and plating was dried and heated in a hot air oven at 160 °C for 2 h to disinfect it. Rubber corks were autoclaved for 15 min at 121 °C. Tryptone, yeast extract, glucose, sodium chloride, Agar bacterial grade, and distilled water were combined to create a growth medium. Hydrochloric acid and sodium hydroxide (1 N) was used to alter the medium's pH. (1 N). The medium was put into bottles that were autoclaved and was refrigerated. After sterilization, each dilution bottles were filled with phosphate buffer with each having 99 mL of blanks. A pipette was used to add 1 mL of the substance to the first dilution, resulting in a 1:100 dilution. Taking 1 mL from the previous bottle and adding it to the new one produced a subsequent dilution of 1:1000. The growth medium present in the ampoule was liquefied over hot water. The plates received around 15 mL of the liquefied liquid at 44 °C. Each plate was carefully mixed with the test portions in the petri dish. The mixture was allowed to congeal. The plates were then inverted and placed in the incubator. For 48 h, plates were incubated at 37.0 ± 0.51 °C. All colonies were counted and recorded after incubation.

2.7.2. Yeast and mould

The [37] technique was employed for the test for yeast and mould. The jam sample was diluted 10^{-1} times with water that contained 0.1% peptone. It was homogenized and pipetted to 15.0x100.0 mm Petri plates with labels already on them. The plates were filled with dichloran 18% (DG18), agar (184), and the contents were mixed before the plates were incubated for five days in the dark at 250 °C. Growth was then measured.

2.7.3. Coliforms

The coliforms in the jam products were examined using [38], 990.11 Official Methods of Analysis. Equipment for sampling and plating was dried and heated in a hot air oven at 160 °C for 2 h to disinfect it. Using an autoclave set at 121 °C for 15 min, media and materials like rubber cork were disinfected.

2.8. Sensory evaluation

The sensory test was done at the University for Development Studies' Department of Food Science and Technology's food processing sensory room by the methods described by Ref. [39]. Before the sensorial studies, the jams were held at 28 ± 2 °C for 24 h. Each panellist was offered 45 g of the jam placed in a 40 mL transparent plastic plate branded with random 3-digit figures. The panellists received water and unsalted crackers as palate cleaners in between samples [40,41]. After getting the panellists' informed consent, 87 untrained students—60 men and 27 women—enrolled in the Food Science and Technology program who are familiar with jams and can eat them without experiencing an allergic response were enlisted to take part in the sensory evaluation trials. furthermore, the panellists were again screened based on [40,41] screening procedure. The sensory test was performed in a room with cool, well-lit light-emitting diodes, and evaluations were carried out at a table with privacy dividers. Based on taste, colour, aroma, and overall product acceptance a five-point hedonic scale (5 = like extremely, 4 = like moderately, 3 = neither like nor a dislike, 2 = dislike considerably, 1 = dislike) was used instead of a nine-point hedonic scale, because the five-point hedonic scale is easy to adopt without additional training, also in terms of sample preference five-point hedonic scale and the nine-point hedonic scale showed no difference [42]. Before tasting the products, the panellists were instructed to assess the colour and aroma of the jam. To prevent biases, specific information on the different types of the jam was kept from the panel members during the study. Using Latin square investigative design, the jam samples were presented in a sequential monadic pattern [40,43,44].

2.8.1. Permission, ethical approval, and consenting

Consent to participate in the study was obtained from the panellists. Permission and ethical approval to conduct the study was obtained from the Department of Food Science and Technology. Faculty of Agriculture, Food and Consumer Sciences, University for Development Studies.

2.9. Statistical analysis

Using Xlstats Statistical Software version 21, the data were subjected to one-way ANOVA, with significance set at a 95% confidence level. When a significant difference (P<0.05) was found, a post hoc test (LSD) was performed. The findings are summed up and presented as means in a table or graph. The correlation matrix of the physico-chemical characteristics and the standardized sensory responses underwent a principal component analysis (PCA). A combined data with the processed jam-type (scores) and their properties were used for this investigation (loadings). The outcomes were displayed as 3D plots, where both the properties (loadings) and processed jam type (scores) were plotted. It was done with the statistical software Origin-Pro 2021.

3. Results and discussion

3.1. Energy value and the nutritional composition of the jam formulations

The results in Table 1 show the energy value and nutrient composition of the jam samples. In this study, it was discovered that the OFSPP

Table 1
Physicochemical and microbiological properties of different OFSPP and PP jam formulations.

Parameter	70% OFSPP: 30% PP	50% OFSPP: 50% PP	30% OFSPP: 70% PP	100% PP	P-value
Energy (Kcal)	279.74 ± 0.14^a	262.60 ± 0.11^b	252.05 ± 0.10^c	256.85 ± 0.03^c	0.021
Moisture (%)	23.70 ± 0.54^c	30.60 ± 0.30^b	34.39 ± 0.31^a	35.31 ± 0.20^d	0.031
Ash (%)	0.40 ± 0.05^a	0.35 ± 0.05^a	0.31 ± 0.06^a	0.29 ± 0.07^a	0.001
Fat (%)	0.18 ± 0.00^d	0.16 ± 0.00^b	0.17 ± 0.00^{bc}	0.25 ± 0.01^d	0.021
Protein (%)	1.84 ± 0.18^a	1.57 ± 0.01^b	0.93 ± 0.01^c	0.41 ± 0.04^d	0.002
Carbohydrate (%)	67.69 ± 0.68^a	63.72 ± 0.26^b	61.70 ± 0.25^c	63.23 ± 0.24^d	0.001
Total dietary fibre	6.19 ± 0.21a	3.60 ± 0.38b	2.50 ± 0.28^b	0.51 ± 0.32d	0.040
Vitamin C (%)	19.20 ± 3.79^b	22.68 ± 3.87^a	25.30 ± 1.82^a	30.20 ± 1.83^a	0.001
Beta Carotene (μg/100g)	0.75 ± 0.01^a	0.29 ± 0.00^b	0.04 ± 0.01^c	nd	0.023
°Brix	64.56 ± 0.30^d	64.68 ± 0.29^c	64.79 ± 0.93^b	65.40 ± 0.10^a	0.001
pH	3.02 ± 0.01^b	3.04 ± 0.01^a	3.1 ± 0.01^c	3.20 ± 0.03^d	0.034
Total plate count (CFU)/g	4.50 ± 0.03^a	4.50 ± 0.12^a	6.50 ± 0.07^a	8.00 ± 0.32^a	0.001
Yeast and mould (CFU)/g	nd	nd	nd	nd	–
Coliform (CFU)/g	nd	nd	nd	nd	–

Values are mean ± standard deviation. Values with the different superscripts within the same row are significantly different (P <0.05). nd: non-detected: OFSPP (Orange-fleshed sweet potato pulp); PP (pineapple pulp); Results on the jam nutrient composition are on a dry matter basis.

throughout the jam-making process substantially impacted the energy content of three OFSPP-PP jams. The energy content of each OFSPP-PP jam under investigation varied significantly (Table 1), with a mean value ranging from 252.1 to 279.7 kcal/100 g. The lowest value was found in the 30% OFSPP-PP jam, whereas the mean energy content of the 70% OFSPP-PP jam was considerably (P<0.05) higher than that of other processed OFSPP-PP Jam. Jam produced with 70% OFSPP also had significant calorie and carbohydrate levels. As a result, OFSP, like other starchy root and tuber crops, can provide ingredients for dietary energy-producing foods for humans and animals [45,46]. The OFSPP-PP's jams different protein and fat contents may have contributed to the observed variances in energy content in the OFSPP-PP jam [45].

All the jams examined had varying levels of moisture (P<0.05), ranging between 23.7 and 35.3%, corroborating other findings from roselle [47] and other fruit jams [48]. Also, there was a reduction in moisture with an increasing level of OFSPP incorporation as compared with that of 100% PP.

Compared to other jams with varying OFSPP concentrations, the fat level of the 100% PP formulation was significantly different **(Table 1)**, showing a higher fat (0.25%) content. In general, jam products with OFSPP had a significantly (P<0.05) lower fat content than jams with 100% PP but were still within the range of fruit jam fat of 0.1–0.2 g/100 g [23,24].

The processed jams' protein content ranged from 0.93% to 1.84%. In addition, the treated jams differed significantly (P<0.05). The protein level of those prepared with 30% OFSPP was 0.93%. The protein content of the processed jams increased significantly (P<0.05) as the concentration of OFSPP increased. The greater protein content could be due to the OFSP peels, which likely kept the protein in the boiling OFSP [49]. In comparison to this study, the protein content of other jams was 0.27 g/100 g for grape jam, apricot jam (0.43 g/100 g), blueberry jam (0.31 g/100 g), strawberry jam (0.41 g/100 g), jackfruit (0.19 g/100 g), and pineapple jam (0.46 g/100 g) [23,50].

The processed jams differed considerably (P<0.05) in carbohydrate content. However, compared to the other processed jams, it was shown that 70% of OFSPP had the most significant total carbohydrate load (67.69%). These results revealed that jams with a more significant proportion of OFSPP had a higher total carbohydrate content during the jam-making process. The quantity of sugar >50 g/100 g in jams may be connected to higher carbohydrate content [48]. Ref. [51] found that the carbohydrate content of pineapple and jackfruit jams ranged from 14 to 48 g/100 g.

The 70% OFSPP formulation had a significantly (P<0.05) higher TDF concentration than the 100% PP jam in terms of TDF. This could be attributed to the jam's high concentration of OFSPP, which likely enhanced the jam's dietary fibre level [2]. Formulations containing 50% OFSPP and 30% OFSPP, on the other hand, were not substantially different at P<0.05. According to another study, jams made with grape, strawberry, and blueberry TDF contained 1.3 and 3.8 g/100 g of TDF [52]. TDF values for orange, plum, and guava jams were 0.3–5.2 g/100 g [53].

Concerning ash content, jams made from 100% PP had a considerably (P<0.05) lower ash (0.29%) content than jams made from OFSPP: PP, which varied from 0.32 to 0.40%. Even though the ash content in this study ranged from 0.29% to 0.40%, it was equivalent to the ash content in jack fruit pineapple jam [51].

The vitamin C concentration of the jam samples ranged from 19.2% to 30.2%, with 100% PP formulations having a higher (30.21%) vitamin C content than OFPP: PP jams **(Table 1).** Because PP is a potential source of vitamin C, this was expected. However, it was clear that lowering the concentration of OFSPP while increasing the concentration of PP enhanced the amount of vitamin C in the OFSPP: PP jams. In terms of β–carotene concentration, the jam manufactured with 70% OFSPP had the highest (0.75 g/100 g) β–carotene level compared to the other jam formulations. An increase in the amount of OFSPP in a jam resulted in an increase in the amount of β-Carotene in a jam. This may be owing to the high β–carotene content of OFSP [28,30], which likely contributed to the increase in β–carotene concentration in the OFSPP: PP jams.

3.2. Total soluble solids (°Brix) and pH of the jam

The total soluble solids (°Brix) content of the jams ranged from 64.79 to 65.40° Brix, with the 100% PP jam having the highest. Among the OFSPP incorporated level, increasing levels led to higher °Brix. The ° Brix content of the OFSPP: PP jam was lower than that of fruit jams. The TSS of Jamun jam, for example, was reported to be 68.3° Brix by Ref. [54].

The pH of the OFSPP: PP jam ranged from 3.1 to 3.2, with a significant difference at P< 0.05, as indicated in Table 1. This result is comparable to Ref. [55] findings on jams. Compared to jams created with 30% and 50% PP, an increase in the PP (70%) resulted in a dip in the pH value. The jam made entirely of PP had a pH value of 3.2. The pH of the jam is crucial in achieving the best gel state [56]. This study's pH value is acidic, which may help preserve the jam products [57].

3.3. Gelling properties of the formulated jams

The formulated jams' ability to gel suggests the existence of pectin, which can gel, in OFSPP [4] and PP [58,59]. As a result, the gel strength shown (Table 2 & Fig. 1) may depend on the concentration of pectin in the OFSPP [4] and the PP [58,59]. Most likely, as pectin concentration increased, the number of carboxylic-acid groups of the pectin molecules rose as well, reducing repulsive forces and allowing hydrogen bonds to form, which probably strengthened the gelation network [60]. In a study, it was found that jam's ability to gel improved as the pectin proportion increased [61], besides it is frequently mentioned in the literature that an increase in gel strength depends on the rising pectin concentration [60,62].

3.4. Microbial quality of the jam

After the 12th week of storage, the processed jams were tested for microbiological quality, as shown in Table 1. For processed jams, the total plate count was within the permitted limit of colony-forming units [63]. In addition, no coliforms, yeast, or mould were found in any of the processed jam samples [33,35,36]. suggest that the presence of β-Carotene and acidic characteristics in processed jams may prevent the growth of microbes. Furthermore, this finding shows that the processed jams meet health and hygienic standards for jam processing.

3.5. Sensory properties of jam

As shown in the radar plot (Fig. 2), all processed jams tasted considerably different, but the formed jam made up of 50% OFSPP had the greatest mean taste score (4.08) compared to 100% PP, which had the lowest mean taste score of 2.43. This demonstrates that a 50% OFSPP congestion was selected. OFSPP (50%) jam scored higher in terms of colour (4.07). OFSPP (70%) got the lowest score value of 3.10 when it came to the aroma of the jams (Fig. 2). The fragrance with the

Table 2
Viscosity values of the formulated jam.

Jam type	Peak viscosity [Pa*s]	Final viscosity [Pa*s]
70% OFSPP: 30% PP	1.041 ± 0.00^{a}	7.685 ± 0.00^{e}
50% OFSPP: 50% PP	9.240 ± 0.00^{b}	7.409 ± 0.00^{f}
30% OFSPP: 70% PP	8.617 ± 0.00^{c}	6.610 ± 0.00^{g}
100% PP	5.390 ± 0.00^{d}	4.798 ± 0.00^{h}

Values are mean ± standard deviation. Values with the different superscripts within the same column are significantly different (P <0.05); OFSPP (Orange-fleshed sweet potato pulp); PP (pineapple pulp).

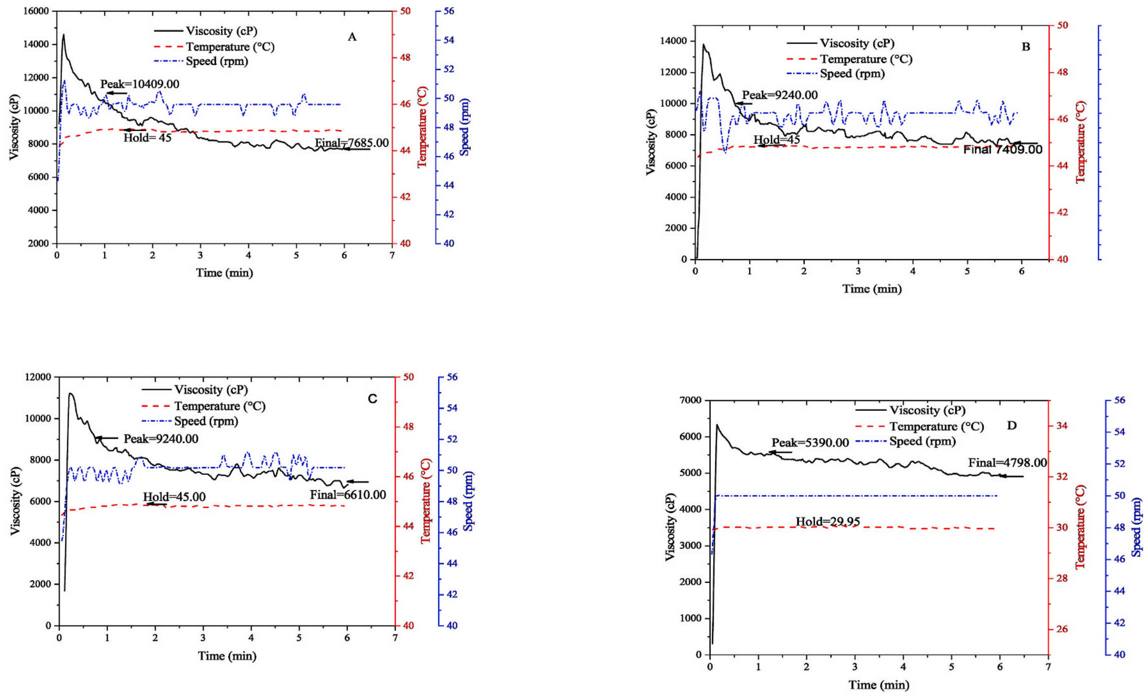

Fig. 1. Gel profile of the processed (70% OFSP puree and 30% Pineapple pulp) jam (A); Gel profile of the processed (50% OFSP puree and 50% Pineapple pulp) jam (B); Gel profile of the processed (30% OFSP puree and 70% Pineapple pulp) jam (C); Gel profile of the processed (100% Pineapple) jam (D).

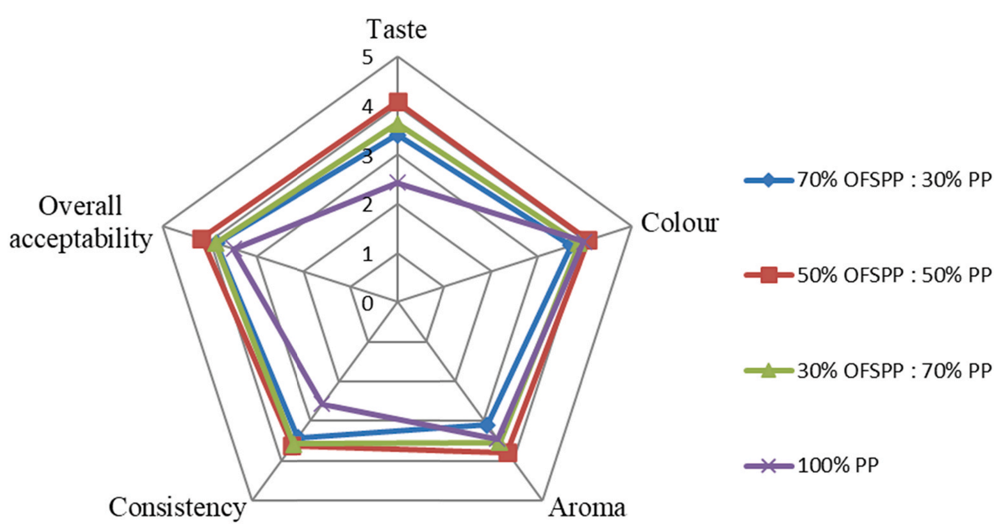

Fig. 2. Sensory attributes of OFSPP-PP jam.

highest score (3.79) was 50% OFSPP jam. In terms of overall consumer liking, the 30%, 50%, 70%, OFSPP jam, and 100% PP jam obtained overall liking scores of 3.88 ≈ 4.00; 4.18; 3.85 ≈ 4.00; and 3.49 ≈ 4.00 respectively, 30% OFSPP; 50% OFSPP; 70% OFSPP, and 100% PP jams were located in the "like moderately' 'region of the hedonic scale. In terms of overall jam acceptability, 50% of OFSPP received the highest grade (4.18) at a significant difference of $P< 0.05$.

3.6. Principal component analysis (PCA) of the processed jam

PCA was performed using all of the physiochemical parameters evaluated to emphasize the distinctive characteristics of each jam (Fig. 3) More than 93.76% of the total variation could be explained by the first two PCs' (PC1 and PC2) highest eigenvalue. In actuality, PC1 accounted for 62.48% of the total, while PC2 made up 31.28%. The jams were thus separated into four groups based on the loading values of the physicochemical and sensory attributes by the correlation between processed jams (scores) and their properties (loadings), as shown in Fig. 3. As a result, PC1 and PC2 were favourable for the first group. It contained the 50:50% OFSPP: PP jam, which was distinguished by having the highest pH, a substantial amount of protein, and the highest level of overall acceptance with the best taste and consistency.

The second group, which had the 70% OFSPP: 30% PP jam, was generated by the jam that was on the opposite side of PC1 and PC2. The highest levels of energy, ash, carbohydrate, total dietary fibre, and beta carotene were found in this jam. The third group, which consisted of 30% OFSPP: 70% PP jams and was located on the positive side of PC2 and the negative side of PC1 was distinguished by its moisture and vitamin C as well as a relatively high level of colour and aroma. The last group, which consisted of jams made entirely of pineapple fruit and

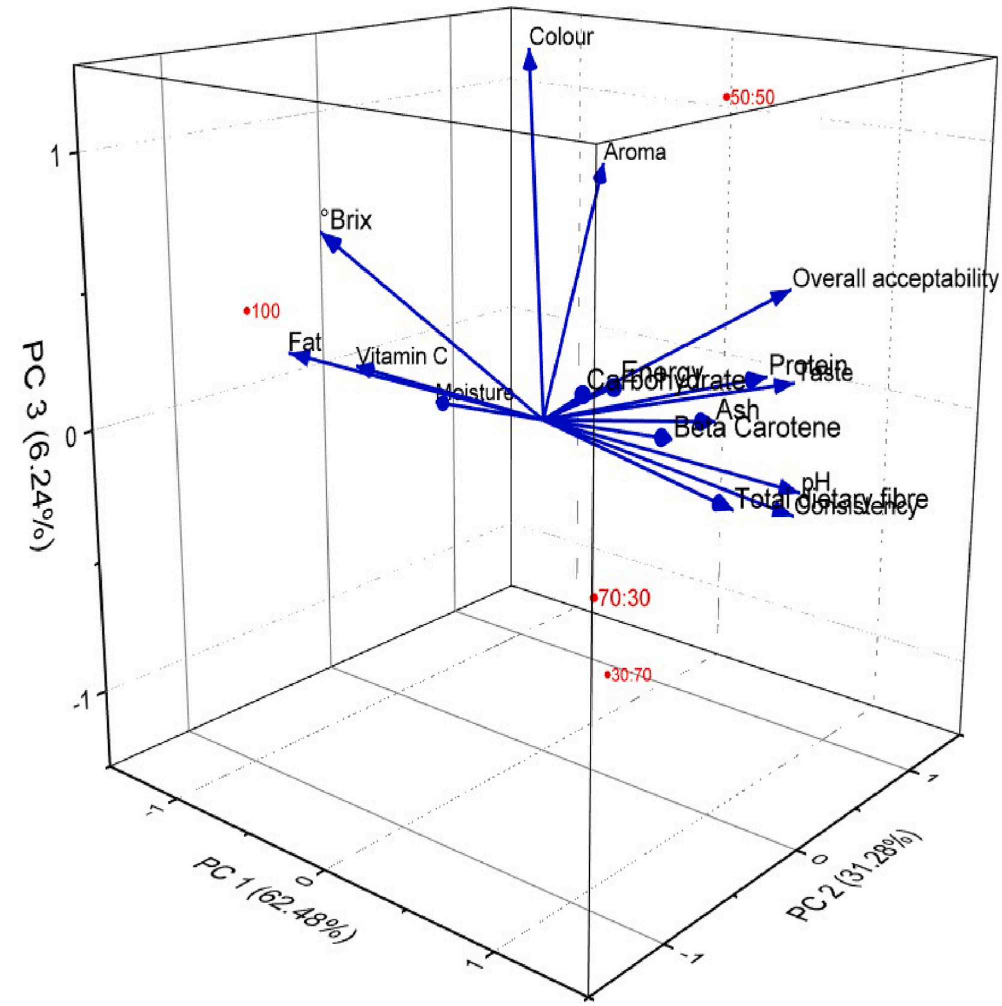

Fig. 3. 3D-plot principal component analysis of the processed jam types.

located on the negative side of PCs 1 and 2, was distinguished by having the highest °Brix and lowest fat level.

4. Scope and limitations of the research

The experimental production of jam using OFSPP and pineapple is described in this work along with the resulting nutritional, physical, gelling, microbiological, and sensory properties of the PP and OFSPP jam. Additional research must be done on the specific water-soluble vitamins, the composition of amino acids, and the HPLC/MS evaluation of the phytochemical elements of the jam. Additionally, it's important to research the processed jam's antioxidant capacities.

5. Conclusions

In conclusion, using OFSPP and PP in jam production improved the fat, TDF, protein, β-Carotene, gelling and sensory properties of the jams, while the PCA revealed that incorporation of OFSPP altered the physical and sensorial properties of the jam, it can be assumed that the best formulation of the jam was 50% OFSP: 50% PP. Also, the microbiological quality of the jams was adequate.

Declaration of competing interest

The authors state that they are aware of no personal or professional conflicts that might have appeared to have impacted the findings provided in this study.

Data availability

Data will be made available on request.

Acknowledgment

This research was possible through the support obtained from the Ghana Tertiary Education Commission (GTEC)/Ghana Government Book and Research grant.

References

[1] J.W. Low, R.O.M. Mwanga, M. Andrade, E. Carey, A.M. Ball, Tackling vitamin A deficiency with biofortified sweetpotato in sub-Saharan Africa, Global Food Secur. 14 (2017) 23–30, https://doi.org/10.1016/j.gfs.2017.01.004.

[2] S. Neela, S.W. Fanta, Review on nutritional composition of orange-fleshed sweet potato and its role in management of vitamin A deficiency, Food Sci. Nutr. 7 (2019) 1920–1945, https://doi.org/10.1002/fsn3.1063.

[3] A.C. Bovell-Benjamin, Sweet potato utilization in human health, industry, and animal feed systems, in: R.C. Ray, K.I. Tomlins (Eds.), Sweet Potato: Post Harvest Aspects in Food, Feed and Industry, Nova Science Publishers, Inc. Chapter, 2010, pp. 193–224.

[4] C. Devi, L. Hynniewta, S. Mitra, Quality evaluation and preparation of jam from sweet potato cultivars, Int. J. Curr. Microbiol. Appl. Sci. 6 (2017) 1485–1492, https://doi.org/10.20546/ijcmas.2017.608.179.

[5] J.W.L. Key, Biofortified crops with a visible trait: the example of orange-fleshed sweet potato in sub-saharan Africa, in: V.R. Preedy, V.B. Patel, R. Srirajaskanthan

(Eds.), Handbook of Food Fortification and Health, Humana Press, New York, NY, 2013, pp. 371–384, https://doi.org/10.1007/978-1-4614-7076-2_25.
[6] F.K. Amagloh, J. Coad, Orange-fleshed sweet potato-based infant food is a better source of dietary vitamin A than a maize-legume blend as complementary food, Food Nutr. Bull. 35 (2014) 51–59, https://doi.org/10.1177/156482651403500107.
[7] B.J. Burri, J.S.T. Chang, T.R. Neidlinger, βcryptoxanthin- and α-carotene-rich foods have greater apparent bioavailability than βcarotene-rich foods in Western diets, Br. J. Nutr. 105 (2011) 212–219, https://doi.org/10.1017/S0007114510003260.
[8] S. Laurie, M. Faber, P. Adebola, A. Belete, Biofortification of sweet potato for food and nutrition security in South Africa, Food Res. Int. 76 (Oct. 2015) 962–970, https://doi.org/10.1016/j.foodres.2015.06.001.
[9] R.P. Tengerdy, N.G. Lacetera, C.F. Nockels, Effect of beta carotene on disease protection and humoral immunity in chickens, Avian Dis. 34 (1990) 848–854, https://doi.org/10.2307/1591372.
[10] D.M. Linares, Teagasc–The Irish Agriculture and Food Development Authority, 2005. Ireland.
[11] E. Gyedu-Akoto, I. Oduro, W.O. Ellis, F.M. Amoah, J.H. Oldham, Utilization of cashew gum in the production of pineapple jam and cashew apple juice drink, Food 4 (1) (2010) 12–16.
[12] S. Guang Ming, X.M. Zhang, A. Soler, P.A. Marie-Alphonsine, Nutritional composition of pineapple (Ananas comosus (L.) merr.), Nutr. Compos. Fruit Cultiv. (Jan. 2016) 609–637, https://doi.org/10.1016/B978-0-12-408117-8.00025-8.
[13] I. Darkwa, The preparation of jam: using star fruit, Glob. J. Educ. Stud. 2 (2) (2016) 21, https://doi.org/10.5296/gjes.v2i2.10032.
[14] V. Chaudhary, V. Kumar, K. Singh, Pineapple (Ananas cosmosus) product processing: a review, J. Pharmacogn. Phytochem. 8 (2019) 4642–4652.
[15] S.A. El-Shazly, M.M. Ahmed, M.S. Al-Harbi, M.E. Alkafafy, H.B. El-Sawy, S.A. M. Amer, Physiological and molecular study on the anti-obesity effects of pineapple (Ananas comosus) juice in male Wistar rat, Food Sci. Biotechnol. 27 (5) (2018) 1429–1438.
[16] W. Xie, S. Zhang, F. Lei, X. Ouyang, L. Du, Ananas comosus L. Leaf phenols and p-coumaric acid regulate liver fat metabolism by upregulating CPT-1 expression, Evid. base Compl. Alternative Med. (2014) 1–12, https://doi.org/10.1155/2014/903258.
[17] E.U. Emmanuel, E.S. Onagbonfeoana, O.C. Adanma, O.C. Precious, A.-I. Faith, O. Y. Ndukaku, In vivo and in vitro antioxidant and hypolipidemic activity of methanol extract of pineapple peels in Wistar rats, Int. J. Biosci. 8 (6) (2016) 64–72.
[18] E.S. Yapo, H.T. Kouakou, L.K. Kouakou, J.Y. Kouadio, P. Kouamé, J.M. Mérillon, Phenolic profiles of pineapple fruits (Ananas comosus L. Merrill) influence of the origin of suckers, Aust. J. Basic Appl. Sci. 5 (6) (2011) 1372–1378.
[19] Y. Oi, I. Hou, H. Fujita, K. Yazawa, Antiobesity effects of Chinese black tea (pu-erh tea) extract and gallic acid, Phyther. Res. 26 (4) (2012) 475–481.
[20] J.R. Ham, H.-I. Lee, R.-Y. Choi, M.-O. Sim, K.-I. Seo, M.-K. Lee, Anti-steatotic and anti-inflammatory roles of syringic acid in high-fat diet-induced obese mice, Food Funct. 7 (2) (2016) 689–697.
[21] T.S. De Melo, et al., Ferulic acid lowers body weight and visceral fat accumulation via modulation of enzymatic, hormonal and inflammatory changes in a mouse model of high-fat diet-induced obesity, Braz. J. Med. Biol. Res. 50 (2017).
[22] Jelly Jam, Preserves Market Size, Share & forecast 2029," *data Bridge market research*. https://www.databridgemarketresearch.com/reports/global-jam-jelly-and-preserves-market, 2022. (Accessed 19 January 2023).
[23] F. Teixeira, et al., Addition of orange peel in orange jam: evaluation of sensory, physicochemical, and nutritional characteristics, Molecules 25 (7) (2020) 1670.
[24] Exporting processed fruit and vegetables and edible nuts to Europe | CBI, in: https://www.cbi.eu/market-information/processed-fruit-vegetables-edible-nuts. (Accessed 19 January 2023).
[25] I. B. de G. e E. (IBGE), Instituto Brasileiro de Geografia e Estatística (IBGE)," *Censo Agropecuário*, 2017. https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario-2017. (Accessed 29 December 2019).
[26] M. Abid, H. Yaich, H. Hidouri, H. Attia, M.A. Ayadi, Effect of substituted gelling agents from pomegranate peel on colour, textural and sensory properties of pomegranate jam, Food Chem. 239 (2018) 1047–1054.
[27] S.A. Featherstone, Processing procedures for canned food products, in: Complete Course in Canning and Related Processes, third ed., Elsevier, Waltham, MA, USA, 2015.
[28] Economics (Product Advantages) - PROFEL, 2019. https://profel-europe.eu/product-advantages/economics/. (Accessed 19 January 2023).
[29] F.K. Amagloh, J.L. Weber, L. Brough, A. Hardacre, N. Anthony, J. Coad, Complementary food blends and malnutrition among infants in Ghana : a review and a proposed solution, Sci. Res. Essays 7 (9) (2012) 972–988, https://doi.org/10.5897/SRE11.1362.
[30] Jelly Jam, Preserves Market Size, Share & forecast 2029," data Bridge market research. https://www.databridgemarketresearch.com/reports/global-jam-jelly-and-preserves-market, 2020. (Accessed 19 January 2023).
[31] N.A. Afoakwah, W.S. Ayyub, Development of Composite Jam from Orange Fleshed Sweet Potato and Pineapple (Unpublished Dissertation), University for Development Studies, 2018.
[32] Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC) International, eighteenth ed., AOAC International, Gaithersburg, MD, Washington, DC, USA, 2005.
[33] E.W. Menezes, A.T. de Melo, G.H. Lima, F.M. Lajolo, Measurement of carbohydrate components and their impact on energy value of foods, J. Food Compos. Anal. 17 (2004) 331–338, https://doi.org/10.1016/j.jfca.2004.03.018.
[34] A.K. Biswas, J. Sahoo, M.K. Chatli, A simple UV-Vis spectrophotometric method for determination of β-carotene content in raw carrot, sweet potato and supplemented chicken meat nuggets, LWT–Food Sci. Technol. 44 (2011) 1809–1813, https://doi.org/10.1016/j.lwt.2011.03.017.
[35] N. Thiex, Evaluation of analytical methods for the determination of moisture, crude protein, crude fat, and crude fiber in distillers dried grains with solubles, J. AOAC Int. 92 (2009) 61–73, https://doi.org/10.1093/jaoac/92.1.61.
[36] G.B. Crosbie, A.S. Ross, The RVA Handbook, AACC International)," *Inc.*, St. Paul, MN, USA, 2007, pp. 6–9.
[37] U. S. Food, "Drug Administration (FDA), Cfsan, Bacteriol, Anal. Man. Online, 2001, pp. 1–6.
[38] AOAC, Method 990.11 Determination of total coliforms and Escherichia coli, in: AOAC. Official Methods of Analysis, 2002, pp. 36–37.
[39] O.P. Chauhan, B.S. Archana, A. Singh, P.S. Raju, A.S. Bawa, Utilization of tender coconut pulp for jam making and its quality evaluation during storage, Food Bioprocess Technol. 6 (6) (2013) 1444–1449.
[40] E. de J. Ramírez-Rivera, et al., Sensory profiles of artisan goat cheeses as influenced by the cultural context and the type of panel, Int. J. Food Sci. Technol. 52 (8) (2017) 1789–1800.
[41] Ramírez-Rivera, Typification of a fresh goat cheese of Mexico by path models, Turk. J. Vet. Anim. Sci. 41 (2) (2017) 213–220.
[42] M. Cheng, et al., Comparative Study on Practicability of 9-Point Hedonic Scale and 5-Point Hedonic Scale for Beverages, Herbalife Int. Inc., 2016, p. 9, no. Table 1, https://www.google.com/search?sxsrf=ALeKk03NDPTTTFqJi6wtyzu6cpTaRk82Hg%3A1595181786210&source=hp&ei=2ooUX_WyCvCZjLsPkuqjcA&q=Comparative+Study+On+Practicability+Of+9-Point+Hedonic+Scale+And+5-Point+Hedonic+Scale+For+Beverages&oq=Comparative+Study+On+Pract.
[43] H.J. MacFie, N. Bratchell, K. Greenhoff, L. V Vallis, Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests, J. Sensory Stud. 4 (2) (1989) 129–148.
[44] E. Périnel, J. Pagès, Optimal nested cross-over designs in sensory analysis, Food Qual. Prefer. 15 (5) (2004) 439–446.
[45] D. Endrias, R. Negussie, D. Gulelat, Comparison of three sweet potato (Ipomoea batatas (L.) lam) varieties on nutritional and anti-nutritional factors, Glob. J. Sci. Front. Res. D Agric. Vet. 16 (4) (2016) 1–11.
[46] A.B. Philip, Root crops in the diets of growing pigs, Livest. Res. Rural Dev. 9 (5) (1991) 387–390.
[47] O.A. Ashaye, T.O. Adeleke, Quality attributes of stored Roselle jam, Int. Food Res. J. 16 (2009) 363–371.
[48] M.N. Mohd Naeem, et al., The nutritional composition of fruit jams in the Malaysian market, J. Saudi Soc. Agric. Sci. 16 (2017) 89–96, https://doi.org/10.1016/j.jssas.2015.03.002.
[49] A.L. Adepoju, B.A. Adejumo, Some proximate properties of sweet potato Ipomoea batatas L as influenced by cooking methods, Int. J. Sci. Technol. Res. 4 (2015) 146–148.
[50] S.U.K. Asema, N. Parveen, Study of heavy metal content by AAS in a variety of flavours of jam samples and its physicochemical characterization, Int. J. Sci. Res. Sci. Eng. Technol 4 (2018) 1259–1261.
[51] J. Eke-Ejiofor, F. Owuno, The physico-chemical and sensory properties of jackfruit (Artocarpus heterophilus) jam, Int. J. Nutr. Food Sci. 2 (3) (2013) 149–152.
[52] M. Roe, S. Church, H. Pinchen, P. Finglas, Nutrient Analysis of Fruit and Vegetables, 2013.
[53] P. Ramulu, P.U. Rao, Total, insoluble and soluble dietary fiber contents of Indian fruits, J. Food Compos. Anal. 16 (2003) 677–685, https://doi.org/10.1016/S0889-1575(03)00095-4.
[54] S.G. Jaiswal, M. Patel, S.N. Naik, Physico-chemical properties of Syzygium cuminii (L.) Skeels jam and comparative antioxidant study with other fruit jams, Indian J. Nat. Prod. Resour. 6 (2015) 9–15.
[55] A.K. Ahmed, S.W. Ali, K. ur Rehman, S. Manzoor, S.R. Ayub, M. Ilyas, Influence of sugar concentration on physicochemical properties and sensory attributes of sapodilla jam, PeerJ Prepr 4 (2016), https://doi.org/10.7287/peerj.preprints.1777.
[56] M. Javanmard, J. Endan, A survey on rheological properties of fruit jams, Int. J. Chem. Eng. Appl. (2010) 31, https://doi.org/10.7763/ijcea.2010.v1.6. –37.
[57] K. Oo, S. Than, Study on physico-chemical properties and shelf- life of mixed pineapple and mango jam under ambient storage, Int. J. Adv. Res. Publ. 3 (2019) 4–8.
[58] B.M. Yapo, Pineapple and banana pectins comprise fewer homogalacturonan building blocks with a smaller degree of polymerization as compared with yellow passion fruit and lemon pectins: implication for gelling properties, Biomacromolecules 10 (4) (2009) 717–721.
[59] M. Lumbanraja, et al., Microwave-assisted extraction and characterisation of pectin from pineapple biomass, AIP Conf. Proc. 2583 (1) (2023), 90015.
[60] O. Yuliarti, A.L.S. Hoon, S.Y. Chong, Influence of pH, pectin and Ca concentration on gelation properties of low-methoxyl pectin extracted from Cyclea barbata Miers, Food Struct. 11 (2017) 16–23.
[61] T.M. Karpinski, A. Adamczak, Fucoxanthin — an antibacterial carotenoid, Antioxidants 8 (2019).
[62] A. Rascón-Chu, A.L. Martínez-López, E. Carvajal-Millán, N.E.P. de León-Renova, J. A. Márquez-Escalante, A. Romo-Chacón, Pectin from low quality 'Golden Delicious' apples: composition and gelling capability, Food Chem. 116 (1) (2009) 101–103.
[63] New South Wales (NSW Food Authority), Microbiological quality guide for ready to-eat foods. A guide to interpreting microbiological results, NSW Food Auth (2009) 9.