


# The effect of kappa-carrageenan and gum Arabic on the production of guava-banana fruit leather

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**Abstract** Guava-banana fruit leather was made by heat-drying a mixture of guava puree, banana puree, sorbitol, kappa-carrageenan or gum Arabic, and water at 60 °C for 8 h in various formulations (F1 to F6). Each formulation was evaluated for its effect on water activity, texture, surface color, proximate composition, pH, ascorbic acid content, antioxidant activity, and sensory properties. Hydrocolloid kappa-carrageenan was found to be the most significant independent variable affecting the desired properties. However, using gum Arabic was more effective at maintaining both water activity and ascorbic acid levels, as well as improving starch digestibility in vitro. In general, there was no discernible effect of the guava to banana ratio in any formulation. While hydrocolloids have no effect on the texture of guava-banana fruit leather, they do affect other sensory characteristics such as color, aroma, taste, and overall. In general, panelists preferred fruit leather made with a 50:50 (F1), 40:60 (F3), or 30:70 (F6) guava-banana ratio and containing kappa-carrageenan.

**Keywords** Fruit leather · Guava-banana · Kappa-carrageenan · Gum Arabic · Starch digestibility

## Introduction

Fruit consumption has long been symbolic of the trend toward a healthier lifestyle, especially in light of the ongoing COVID-19 pandemic (Ruiz-Roso et al., 2020). For instance, fruit leather can serve as a low-cost and convenient value-added alternative to natural fruits in terms of supplying a variety of nutrients, most notably vitamin C (Bandaru & Bakshi, 2020; Huang & Hsieh, 2005). Additionally, it can be a beneficial outlet for low-quality fruits and by-products from other fruit-based processes. Furthermore, fruit leather, like the majority of restructured fruits, is lower in calories (less than 100 kcal per serving) than a variety of other snacks.

Fruit leather, also called fruit sheet or fruit flexible strip, is produced by drying fruit puree or a mixture of fruit juice concentrate and other ingredients on a flat surface in an oven, hot air dryer, or direct sunlight (Diamante et al., 2014). Its product is one way to preserve fresh fruit for long term consumption (Bandaru & Bakshi, 2020). Fruit leather is a well-known product, especially in North America and Europe (Shafi'i et al., 2013). Almost any type of fruit, either alone or in combination, can be used to make fruit leather, including apples, bananas, pineapple, peaches, guava, and papaya. Fruit leather is ideal for on-the-go consumption due to its portability and high protein and fiber content. In addition, fruit leathers are an economic and convenience substitute for natural fruits with high nutritional components.

Guava (*Psidium guajava* L.) and banana (*Musa* spp.) are two tropical fruits with distinct flavors that are also delicious, digestive, and nutritious. Guavas are a good source of vitamin C, while bananas are a good source of potassium (Islam et al., 2019). Apart from that, both fruits contain a variety of health-promoting phytochemicals, including vitamins, minerals, antioxidants, and dietary fiber (Chaudhry

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& Farooqi, 1970). Combining different fruits through the process of making nutritious fruit leather may be explored in order to benefit from both fruits' phytonutrient content. Guava fruit, with its pink pulp and pleasant flavor, can be combined with bananas, which have a white pulp and a pleasant flavor and aroma, to produce a premium product.

Hydrocolloids are commonly used as thickening and gelling agents in many food formulations to improve quality and shelf life. They are widely used as thickening and gelling agents (Frediansyah, 2021). Furthermore, hydrocolloids play an important role in maintaining the desired texture of fruit leathers as well as improving their self-life, physical, and chemical properties (Barman et al., 2021).

In general, the formulation of guava-banana fruit leather in our previous study lacked extensibility and chewiness. From this point of view, the use of hydrocolloids (gum Arabic and kappa-carrageenan) could be an effective way to improve the products. In addition, improving the quality of the products during processing and storage could improve the premium label of the products. Thus, the present work is aimed at examining the use of hydrocolloids as a possible alternative method for enhancing the physicochemical properties of fruit leather, as well as the contribution of each variable and its interactions to the extensibility of guava-banana fruit leather. Additionally, texture characteristics have been analyzed, which are critical for consumer acceptance.

## Material and Methods

### Materials

Red guava (*Psidium guajava* L.), banana (*Musa corniculata* Rumph), and sorbitol. Hydrocolloids (kappa-carrageenan and gum Arabic) were used to enhance the physicochemical properties of fruit leather and were purchased from a local market in Yogyakarta, Indonesia. Guava and banana were kept chilled at 4 °C until they were used in the experiments (within 24 h), enhancing the physicochemical properties of fruit leather.

### Preparation of guava-banana puree mixture

Peeled, sliced, and cored guavas were blended into a puree along with pureed banana, sorbitol, kappa-carrageenan, and gum Arabic according to the formulation shown in Table 1. Kappa-carrageenan and gum Arabic were dissolved into water at 95 °C prior to use. To obtain a smooth mixture, the blending process was carried out at a high speed for 5 min. Each run required a total of 400 g of puree mixture. The puree mixture was poured into a nonstick aluminum tray with an interior dimension of 28 × 28 × 2 cm. The aluminum tray was filled to the brim with approximately 310 g of puree mixture.

### Heat-drying experiments

The trays containing the fruit puree mixtures were placed in the dryer's middle and upper sections, while the dryer's center was equipped with a temperature data logger. The drying time was 8 h, the average drying temperature was 60 ± 2 °C, and the air velocity perpendicular to the sample was 0.20 m/s. Local data loggers in a dryer cabinet were used to monitor the dry temperature, ambient temperature, and relative humidity during the experiment.

### Water activity ( $a_w$ ) measurement

Water activity was determined three times per treatment, using fruit leather cut into approximately 2 × 2 mm pieces and a portable water activity meter (Humimeter RH2). The mean water activity per treatment was calculated at a temperature of 25 ± 0.5 °C. Water activity values of less than 0.60 suggest that the fruit leather is microbially stable. Low water behavior results in a rugged, dry fruit leather.

### Texture measurements

The textural property of each formulation of guava-fruit leather was determined using a Llyod universal testing machine (Zaick/z0.5) by measuring the force required to

**Table 1.** Formulation of guava-banana fruit leather.

Materials	F1	F2	F3	F4	F5	F6
Guava puree (g)	100	100	80	80	60	60
Banana Puree (g)	100	100	120	120	140	140
Sorbitol (g)	19.6	19.6	19.6	19.6	19.6	19.6
Water (ml)	180	180	180	180	180	180
Kappa-carrageenan (g)	1.2	0	1.2	0	0	1.2
Gum Arabic (g)	0	1.2	0	1.2	1.2	0

\* F1 (also referred to as 50:50 (guava: banana) with kappa-carrageenan), F2 (also referred to as 50:50 (guava: banana) with gum Arabic), F3 (also referred to as 60:40 (guava: banana) with kappa-carrageenan), F4 (also referred to as 60:40 (guava: banana) with gum Arabic), F5 (also referred to as 30:70 (guava: banana) with gum Arabic), F6 (also referred to as 30:70 (guava: banana) with kappa-carrageenan).

puncture the fruit leather sheet. To support the fruit leather sheet, a heavy-duty platform with a hole in the center was used. To secure the sample, a 500 g stainless steel cylinder with a hole in the center was placed on top of it. The sample was punctured with a 2 mm cylindrical probe. The test speed was set to 1.0 mm/s, the trigger force to 5 g, and the probe travel distance to 10.0 mm. The cylindrical probe was brought very close to the sample, and then the test was initiated and continued until the sample was punctured. Three times at different points, the different fruit leathers were measured. The data on the tensile strength (Newton) was then analyzed.

### Surface color analysis

The surface color values (CIE  $L^*$ ,  $a^*$ , and  $b^*$ ) of various formulations of guava-banana fruit leather were determined using a Chromameter CR-20 (Konica Minolta, Sensing Inc., Tokyo, Japan) as described in Frediansyah, Praharasti, et al. (2017b). Prior to each measurement, the instrument was calibrated with a white ceramic tile ( $L^* = 98.06$ ,  $a^* = 0.23$ ,  $b^* = 1.88$ ). To fill a petri dish, the samples are cut into 2 × 2 mm pieces and then measured three times at different points. The chroma ( $C^*$ ) and hue ( $h^*$ ) of the samples were determined using the following equation:

$$C^* = [(a^*)^2 + (b^*)^2]^{1/2} \quad (1)$$

$$h^* = \tan^{-1}(b^*/a^*) \quad (2)$$

where  $a^*$  and  $b^*$  are the samples' color values.

A high chroma value indicates a deep red color for the fruit leather, while a high hue value indicates the lighter of the samples.

### Proximal and pH analysis

The proximal analysis of the guava-banana fruit leather formulations was performed at the Research Center for Food Technology and Processing (PRTPP), National Research and Innovation Agency (BRIN) using the following methods: Kjeldahl, using 6.5 as a conversion factor to determine protein content (AOAC, Official Method 984.13 (A-D), 2006); ash determination (AOAC, Official Method 942.05, 2006); water content determined using a vacuum oven (AOAC, 2006); total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber (IDF) (AOAC, Official Method 985.29 and Official Method 991.43, 2006) (SDF was determined by subtracting TDF from IDF.) Pectin was therefore analyzed using precipitation/photometry in accordance with IFU Method No. 26 (1964/1996). The pH of samples was measured using the Eutech PC 700 (Thermo Scientific, IL, USA).

### Ascorbic acid content

About 1 g of guava-banana fruit leather from each formulation was taken and extracted using 20 ml of the solution (16:4 v/v, methanol water). The extract was then placed in an incubator shaker at 30 °C for 5 h. The extracts were then centrifuged at 10,000 rpm for 10 min. The supernatant was then collected for further analysis. Ten milliliters of each supernatant from sample formulation were placed into a 100 mL volumetric flask and brought into volume with 0.4% oxalic acid solution. The solution was then filtered using a Whatman no. 4 filter paper. Ten milliliters of the filtered solution were pipetted into conical flask along with 15 ml of 0.4% oxalic acid solution. The obtained solution was then titrated using a micro-burette with 0.04% aqueous sodium dichlorophenolindophenol solution to first pink shade. The sodium dichlorophenolindophenol solution was standardized with sodium thiosulphate 0.01 N in a matrix of potassium iodide (50%) and HCl 1 N using starch indicator. The following equation was used to calculate the ascorbic acid content:

$$\begin{aligned} \text{Ascorbic acid (mg/100g S)} \\ = [(0.5\text{mg}/V_1) \times (V_2/15\text{ml}) \times (100\text{ml}/\text{weight of S}) \\ \times 100 \end{aligned} \quad (3)$$

where,  $V_1$  = titer volume of ascorbic acid standard (ml),  $V_2$  = titer volume of the sample (ml); and S = sample.

### Antioxidant activity

The DPPH (1,1-diphenyl-2-picrylhydrazyl) radical-scavenging ability of extrudate guava-banana fruit leather was evaluated according to Frediansyah, Nurhayati, and Romadhoni (2017a). In brief, 50  $\mu$ l of filtered filtrate was mixed with 70  $\mu$ l of methanol, and the absorbance of the pre-plate reading was recorded at 517 nm. About 80  $\mu$ l of 0.5 mM DPPH solution in methanol was then added to the well. The degree of purple (from DPPH) decolorization to yellow presented the scavenging efficiency of filtrate. After an incubation period of 30 min at room temperature ( $25 \pm 2$  °C) in the darkness, the decrease in the absorbance was recorded at 517 nm in the Multiskan<sup>®</sup>Go microplate spectrophotometer (Thermo Scientific, Vantaa, Finland). Lower absorbance of the reaction presented higher free radical-scavenging activity. The scavenging activity against DPPH was calculated using the equation:

$$\text{DPPH scavenging rate (\%)} = [1 - (Abs_1 - Abs_0) \times 100\%] \quad (4)$$

where  $Abs_0$  was the absorbance of control and  $Abs_1$  was the absorbance in the presence of filtrate.

## In vitro starch digestibility

The method of Englyst et al. (1992) as modified by Chung, Lim, and Lim (2006), was used to determine the in vitro digestibility of starch. The amount of digestible starch fractions was calculated using the method of Englyst et al. (1992), with minor modifications due to the slow digestion of prime (ungelatinized) starch. The rapidly digestible starch (RDS) fraction was defined as the starch fraction that was hydrolyzed within 20 min of incubation, whereas the resistant starch (RS) fraction was still unhydrolyzed after 180 min. The difference between RDS and RS was used to compute the amount of slowly digestible starch (SDS).

## Sensory evaluation

Sensory evaluation was performed by an untrained sensory panel of thirty panelists. Each formulation of guava-banana fruit leather was prepared on a plate with a random code. Five sensory attributes, including color, aroma, flavor, texture, and overall, were evaluated on a scale from "0" (not perceivable) to "7" (very strong). To neutralize the panelists' pallets between the tastings of different guava-banana fruit leathers, fresh water was available.

## Statistical analysis

All analyses were performed at least in triplicates. The study employed a completely randomized factorial design, with the ratios of guava and banana puree (50:50, 60:40, and 70:30) and the hydrocolloid (0.3 g kappa-carrageenan and 0.3 g gum Arabic) varied. Six treatment groups were formed. The effect of each treatment on the quality attributes of guava-banana fruit leather was analyzed statistically using a two-way ANOVA followed by the Duncan Multiple Range test ( $P < 0.05$ ).

## Result and Discussion

In this study, pureed guava ( $86.30 \pm 0.5\%$ , db) and pureed banana ( $85.17 \pm 0.6\%$ , db) were used in various ratios of 30:70; 40:60; and 50:50 for guava and banana, respectively, to develop various formulations of guava-banana fruit leather. Sorbitol was present in each formulation at a concentration of 4.9%. Therefore, certain formulations contain hydrocolloid of either 0.3% kappa-carrageenan or 0.3% gum Arabic.

## Effects of fruit ratio and hydrocolloids on chemical composition

The proximal content of the guava-banana fruit leather formulation is summarized in Table 2. The results indicated that when kappa-carrageenan was added to the formulation, the final protein content increased significantly when compared to gum Arabic ( $p < 0.05$ ). This finding is related to a study that discovered carrageenan may improve the physicochemical stability of certain compositions (Song et al., 2021). However, increasing the banana content in the formulation from 50 to 70% had no discernible effect on the dissolved protein content. In this study, the dissolved protein concentration was found to range between 2.25 and 3.61%. These percentages were higher than those for mixed fruit leather, which contains apple, banana, and pineapple and contains between 0.58 and 0.71% ash (Offia-Olua & Ekwunife, 2015), and papaya fruit leather, which contains between 1.42 and 2.25% ash (Ghimire & Ojha, 2016).

The presence of ash in the fruit leather was also related to the mineral content. Thus, the experiment demonstrated that gum Arabic increased the final ash content of the product formulation significantly when compared to carrageenan ( $p < 0.05$ ), as shown in Table 2. Additionally, the elevation of ash is related to the use of banana rations in an elevation-dependent manner ( $p < 0.05$ ). Due to the high mineral content of bananas, adding their external nutrients increases the ash content of fruit leather. Raw bananas contain approximately 0.8% ash (Elayabalan et al., 2017), while guavas contain approximately 1.39% (Chen et al., 2007). The ash content was found to range between 2.83 and 3.44% in this study. These percentages exceeded those for mixed fruit leather, which contains apple, banana, and pineapple and contains ash in the range of 0.97 to 1.20% (Offia-Olua & Ekwunife, 2015), persimmon fruit leather (Mohamed et al., 2018), which contains ash in the range of 1.1 to 1.12%, and papaya fruit leather, which contains ash in the range of 0.94 to 2.08% (Ghimire & Ojha, 2016).

Moisture is a necessary component of food products. A fruit leather with less moisture has a longer shelf life, as water in the product can accelerate enzymatic deterioration and spoilage (R. Singh & Anderson, 2004). Thus, our findings indicated that neither kappa-carrageenan nor gum Arabic had a discernible effect on the water content of the final product. It is, however, elevation-dependently associated with the use of guava rations. In this study, the water content was found to range between 14.79 and 15.75%. These percentages correspond to the range of 16.56 to 19.50% for jackfruit fruit leather (Okilya, Mukisa, & Kaaya, 2010) and 14.79 to 15.75% for guava-papaya fruit leather (J. Singh & Tiwari, 2019). Additionally, the water content was greater than that of persimmon fruit leather

**Table 2.** Effect of guava-banana ratio and hydrocolloids on chemical composition of guava-banana fruit leather.

Chemical Composition (%)	Guava: banana ratio (%)	0.3% Hydrocolloid		
		Kappa-carrageenan	Gum Arabic	Average
Protein content	30:70	3.21±0.02	2.80±0.01	3.00±0.22 <sup>a</sup>
	40:60	3.54±0.06	2.34±0.04	2.94±0.65 <sup>a</sup>
	50:50	3.61±0.02	2.25±0.11	2.93±0.75 <sup>a</sup>
	Average	3.45±0.19 <sup>B</sup>	2.46±0.26 <sup>A</sup>	
Ash	30:70	2.83±0.11	3.16±0.08	2.99±0.14 <sup>a</sup>
	40:60	3.44±0.26	3.39±0.11	3.42±0.15 <sup>b</sup>
	50:50	3.14±0.17	3.39±0.04	3.27±0.17 <sup>c</sup>
	Average	3.14±0.31 <sup>A</sup>	3.31±0.13 <sup>B</sup>	
Water content	30:70	16.56±0.20	17.66±0.25	17.11±0.61 <sup>a</sup>
	40:60	18.32±0.20	18.61±0.24	18.46±0.26 <sup>b</sup>
	50:50	19.25±0.36	19.50±0.10	19.38±0.28 <sup>c</sup>
	Average	18.04±1.17 <sup>A</sup>	18.59±0.79 <sup>B</sup>	
TDF	30:70	13.72±0.03	11.91±0.03	12.82±0.99 <sup>c</sup>
	40:60	12.02±0.08	9.16±0.09	10.59±1.56 <sup>a</sup>
	50:50	12.41±0.11	10.98±0.02	11.70±0.78 <sup>b</sup>
	Average	12.72±0.77 <sup>A</sup>	10.68±1.21 <sup>A</sup>	
IDF	30:70	5.62±0.02	5.65±0.07	5.63±0.05 <sup>a</sup>
	40:60	5.85±0.08	5.87±0.05	5.86±0.06 <sup>b</sup>
	50:50	5.97±0.08	5.95±0.10	5.96±0.09 <sup>c</sup>
	Average	5.81±0.16 <sup>A</sup>	5.83±0.15 <sup>A</sup>	
SDF	30:70	8.10±0.03	6.26±0.05	7.18±0.06 <sup>c</sup>
	40:60	6.17±0.02	3.29±0.03	4.73±0.04 <sup>a</sup>
	50:50	6.44±0.04	5.03±0.09	5.74±0.08 <sup>b</sup>
	Average	6.90±0.14 <sup>A</sup>	4.86±0.13 <sup>B</sup>	
Pectin	30:70	2.06±0.04	1.98±0.01	1.84±0.04 <sup>c</sup>
	40:60	1.90±0.03	1.87±0.03	1.89±0.03 <sup>b</sup>
	50:50	1.83±0.04	1.85±0.05	2.02±0.05 <sup>a</sup>
	Average	1.93±0.10 <sup>A</sup>	1.90±0.06 <sup>A</sup>	

Values denoted by the same superscript (s) are not significantly different within the same column and row at  $p < 0.05$ . The values indicate the mean and standard deviation of three independent measurements. Total dietary fiber is denoted by TDF; insoluble dietary fiber is denoted by IDF; and soluble dietary fiber is denoted by SDF.

(6.36–6.55%) (Mohamed et al., 2018) and papaya-soy fruit leather (11.47–14.46%) (Ghimire & Ojha, 2016).

Bananas and guavas are naturally high in fiber and vitamins, two nutrients that benefit the body’s health. Thus, we are interested in the total dietary fiber (TDF) content of the final guava-banana fruit leather product, as well as the soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) contents, as these nutrients are critical for human health. The research reveals that when kappa-carrageenan was used instead of gum Arabic, the TDF and SDF of the final products increased significantly ( $p < 0.05$ ) (Table 2). Therefore, its kappa-carrageenan had an insignificant effect on the IDF when compared to gum Arabic. The guava/banana ratio also had a significant effect on the total TDF and SDF of each formulation ( $p < 0.05$ ), but not on the IDF. The TDF was found to range between

9.16 and 13.72% in this study. These percentages exceeded those for fruit leather made from Japanese apricots (*Prunus mume* Sieb. et Zucc), which ranged between 4.06 and 7.82%. (Kang, Chung, & Eun, 1999). The IDF was found to range between 5.62 and 5.97% in this study (Table 2). These findings lowered with those obtained with mixed fruit leather (Offia-Olua & Ekwunife, 2015). However, the results obtained with persimmon fruit leather were higher (Mohamed et al., 2018). Food that has been improperly processed loses its fiber content, rendering it unfit for human consumption (Bi et al., 2020).

Additionally, it is common practice to use pectin as an external agent in the processing of fruit leather in order to improve color and texture while simultaneously reducing moisture content and water activity (Diamante et al., 2013). In one study, pectin levels ranging from 0.5 to 1.5% were



**Table 3.** Effect of guava-banana ratio and hydrocolloids on color properties of guava-banana fruit leather.

Surface color	Guava: banana ratio (%)	0.3% Hydrocolloid		
		Kappa-carrageenan	Gum Arabic	Average
$L^*$	30:70	31.83±0.40	32.53±0.93	32.18±0.15 <sup>a</sup>
	40:60	33.92±0.84	33.43±1.65	33.68±0.30 <sup>b</sup>
	50:50	35.36±1.15	32.96±0.97	34.16±0.21 <sup>c</sup>
	Average	33.70±0.82 <sup>B</sup>	32.97±0.43 <sup>A</sup>	
$a^*$	30:70	8.43±0.37	10.86±0.40	9.65±0.18 <sup>b</sup>
	40:60	7.96±1.11	8.46±1.40	8.21±0.11 <sup>a</sup>
	50:50	11.73±1.85	7.76±0.55	9.75±0.12 <sup>b</sup>
	Average	9.37±0.32 <sup>A</sup>	9.03±0.32 <sup>A</sup>	
$b^*$	30:70	9.46±0.05	12.50±0.79	10.98±0.12 <sup>b</sup>
	40:60	11.30±0.17	11.00±1.47	11.15±0.33 <sup>b</sup>
	50:50	10.53±1.25	8.90±1.25	9.71±0.23 <sup>a</sup>
	Average	10.43±1.12 <sup>A</sup>	10.8±1.10 <sup>A</sup>	
$C^*$	30:70	12.67±0.25	16.60±0.89	14.64±0.36 <sup>b</sup>
	40:60	13.83±0.21	13.93±0.96	13.88±0.09 <sup>a</sup>
	50:50	15.76±1.25	12.70±0.10	14.23±0.41 <sup>b</sup>
	Average	14.08±0.89 <sup>A</sup>	14.41±0.76 <sup>A</sup>	
$H_o$	30:70	48.30±1.21	49.13±0.09	48.71±0.65 <sup>b</sup>
	40:60	54.63±0.49	52.27±0.46	53.45±0.95 <sup>c</sup>
	50:50	41.93±1.42	48.73±0.39	45.33±1.45 <sup>a</sup>
	Average	48.28±0.98 <sup>A</sup>	50.03±1.01 <sup>B</sup>	

Within the same column and row, values denoted by the same superscript (s) are not significantly different at  $p < 0.05$ . The values represent the mean and standard deviation of three independent determinations.  $L^*$  denotes light (+) and black denotes darkness (-);  $a^*$  denotes red (+) and greenness (-);  $b^*$  denotes yellow (+) and blueness (-);  $C^*$  (also referred to as Chroma, is a color intensity) and  $H_o$  (hue angle color saturation).

used to improve pineapple fruit leather, with the results showing an improvement. (Phimpharian et al., 2011a). Moreover, our research revealed that the pectin content of the formulation ranges from 1.85 to 2.06% when no pectin is added to the formulation (Table 2).

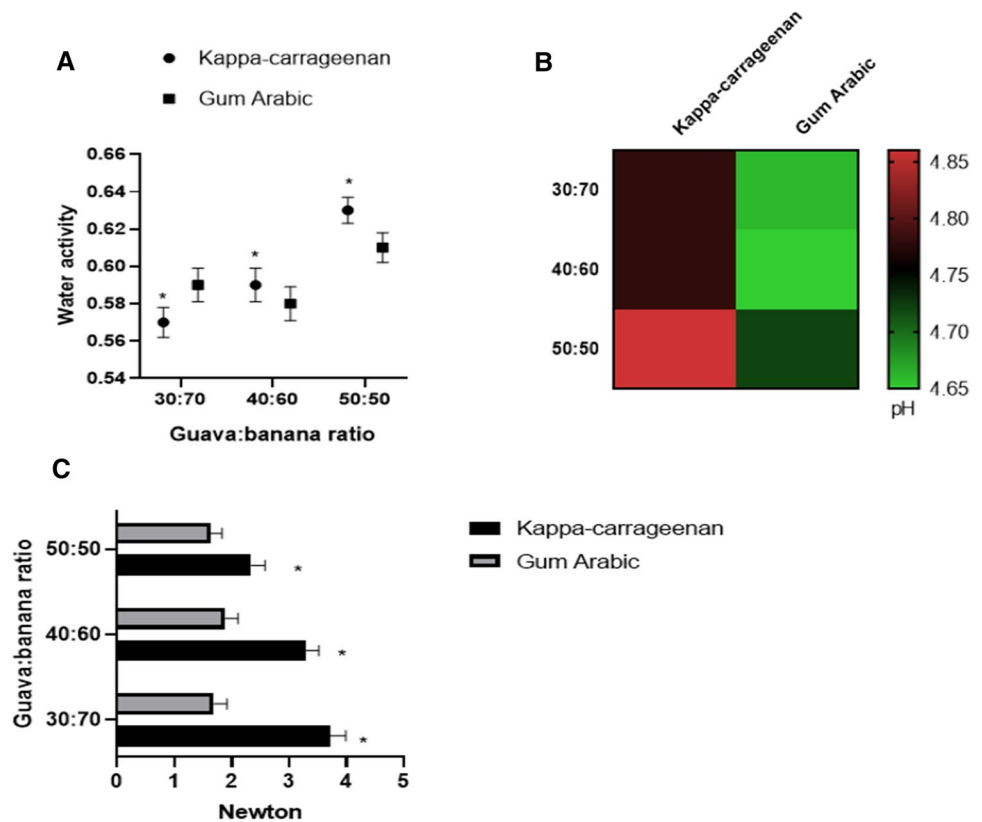
### Effects of fruit ratio and hydrocolloids on color

The banana peel drying process imparted a dark brown color to the fruit leather. The color is altered as a result of the Maillard reaction between the glucose, fructose, and protein found in banana peels and the sorbitol found in the external sugar composition. Additionally, banana peels may contain enzymes such as polyphenol oxidase, which may have caused browning of products caused by enzymes (Lee, 2007). Variations in lightness could also be attributed to the heat-drying process that occurs when fruit leather is exposed to the dryer's surface area and oxidation (Frediansyah, Prarasti, et al., 2017b). Thus, as part of the optimization process, we investigated the color of banana-fruit leather products in various formulations. The color of guava-banana fruit leathers is depicted in Table 3. Hydrocolloid of kappa-carrageenan and gum Arabic had lightness ( $L^*$ ) values of 31.83 to

35.36 and 32.53 to 33.43, respectively. Additionally, kappa-average carrageenan's  $L^*$  value outperformed gum Arabic in light color ( $p < 0.05$ ). In addition, each guava-banana ratio showed a significant difference in lightness, with the formulation containing 50% guava and 50% banana exhibiting the best lightness color ( $p < 0.05$ ). This demonstrates that the addition of kappa-carrageenan and gum Arabic results in a discernible color change. Furthermore, varying the proportion of guava and banana demonstrated varying degrees of lightness. A higher banana percentage resulted in a lower  $L^*$  value on average. This is due to an approximately eight-hour heat-drying process at a temperature of  $60 \pm 2$  °C.

The  $a^*$  values for kappa-carrageenan and gum Arabic were 7.96 to 11.73 and 8.46 to 10.86, respectively (as shown in Table 3). The average of the  $a^*$  values indicated that there was no discernible difference between the kappa-carrageenan and gum Arabic additions. Additionally, when compared to the 30:70 formulation (guava: banana), the 50:50 and 40:60 formulations (guava: banana) demonstrated a significant difference in terms of redness ( $p < 0.05$ ). However, the formulations 50:50 (guava: banana) and 40:60 (guava: banana) did not significantly differ. The yellowness (+) and blueness (-) ( $b^*$ ) values for kappa-carrageenan were

**Fig. 1** The water activities (A); pH values (B); and tensile strength (C) of various formulations of guava-banana fruit leather



9.46 and 11.30, respectively, and 8.90 to 12.50 for gum Arabic. The average  $b^*$  value did not show a significant difference between the additions of kappa-carrageenan and gum Arabic. Additionally, when compared to the 50:50 (guava: banana) formulation, the 30:70 and 40:60 (guava: banana) formulations demonstrated a significant difference in yellowness ( $p < 0.05$ ). However, the formulations 30:70 (guava: banana) and 40:60 (guava: banana) were not significantly different. The majority of the redness in the formulations is due to the presence of red guava. Additionally, as fresh bananas ripen during storage, the color of the peel changes due to the loss of greenness, resulting in an increase in reddish and yellow tones. The observed difference in redness and yellowness could also be explained by the surface area of the fruit leather being dried and stored at a high temperature.

The chroma ( $C^*$ ) values of guava-banana fruit leather, also known as color intensity, ranged between 12.67 and 15.76 for kappa-carrageenan and 13.93 to 16.60 for gum Arabic, respectively (As shown in Table 3). The averaged  $C^*$  values revealed no discernible difference between kappa-carrageenan and gum Arabic additions. Additionally, when compared to the 40:60 formulation (guava: banana), the 30:70 and 50:50 formulations (guava: banana) demonstrated a significant difference in terms of redness ( $p < 0.05$ ). However, the formulations of 30:70 (guava: banana) and 50:50 40:60 (guava: banana) were not significantly different. In

general, a high chroma value indicates that the fruit leather is a deep red purple color.

The Hue angle  $H_o$  of guava-banana fruit leather ranged between 41.93 and 54.63 for kappa-carrageenan and 48.73 to 52.57 for gum Arabic, respectively (As shown in Table 3). Additionally, kappa-average carrageenan's  $H_o$  value outperformed gum Arabic in terms of color saturation ( $p < 0.05$ ). Additionally, each guava-banana ratio showed a significant difference in  $H_o$ , with the formulation containing 40% guava and 60% banana exhibiting the highest color saturation ( $p < 0.05$ ). Additionally, varying the proportions of guava and banana demonstrated varying degrees of  $H_o$ . The difference in chroma and hue values between the guava-banana fruit leather might be due to the ingredient composition and red pigmentation reaction or non-enzymatic browning, which is dependent on the ratio of reducing sugar to amino acids and protein on the surface, as well as time and heat-drying temperature.

### Effects of fruit ratio and hydrocolloids on acidity and water activity

Fruit leather's quality is determined by its water activity ( $a_w$ ) and acidity. Figure 1A illustrates the  $a_w$  of guava-banana fruit leathers. The  $a_w$  values of kappa-carrageenan and gum Arabic were 0.57 to 0.63 and 0.58 to 0.61, respectively. The average  $a_w$  values did not differ

significantly between kappa-carrageenan and gum Arabic additions. Additionally, the 30:70 and 40:60 guava: banana formulations demonstrated a significant difference in water activity ( $p < 0.05$ ) when compared to the 50:50 guava: banana formulation. The average  $a_w$  values of guava-banana fruit leather containing kappa-carrageenan and gum Arabic indicated that the leather showed good water activity ( $a_w \leq 0.6$ ). Among the three guava-banana ratio groups used in fruit leather formulations, an  $a_w > 0.6$  is observed when 50% guava and 50% banana are used. Our findings were consistent with banana fruit leather in general, with  $a_w$  values ranging from 0.59 to 0.7 (Setiaboma, Fitriani, & Mareta, 2019). In addition, it is higher than apple-blackcurrant fruit leather, which ranges from 0.27 to 0.48 (Diamante et al., 2013). A water activity  $\leq 0.60$  indicates that the fruit leather is microbially stable. Due to the low water activity, the fruit leather becomes tough and dry.

Figure 1B illustrates the pH values of fruit-leather formulations using a heat map. The average pH values revealed no significant difference between the additions of kappa-carrageenan (4.81) and gum Arabic (4.78). Additionally, when compared to the 50:50 and 40:60 guava: banana formulations, the 30:70 guava: banana formulation demonstrated a significant difference in pH ( $p < 0.05$ ). Thus, the addition of bananas to fruit leather increases its acidity. Low pH conditions are critical for the formation of structure gels during the fruit leather manufacturing process, as structure gels can only be formed at a low pH. Our results are consistent with persimmon fruit leather having a pH range of 4.11 to 4.16 (Mohamed et al., 2018). Our results, however, are more acidic than mixed fruit leather, which contains apple, banana, and pineapple and has a pH range of 5.93 to 6.11 (Offia-Olua & Ekwunife, 2015), and papaya-soy fruit leather, which has a pH range of 6.00 to 6.33 (Ghimire & Ojha, 2016).

### Tensile strength effects of fruit ratio and hydrocolloids

The tensile strength of an object is the amount of force required to break it. The maximum force ( $F_{max}$ ) required to stretch guava-banana fruit leather to failure determines its tensile strength. The results of the tensile strength test are shown in Fig. 1C. The addition of 0.3% kappa-carrageenan hydrocolloid to fruit leather products significantly increased the tensile strength of guava-banana fruit leather ( $p < 0.05$ ) in all formulations (guava: banana; 50:50; 40:60; 30:70). Fruit leather containing kappa-carrageenan has a tensile strength of between 2.34 and 3.72 Newtons, with an average of 3.12 Newton. However, the tensile strength of the gum Arabic only ranges from 1.63 to 1.84 Newtons, with an average of only 1.74 Newton. The increased  $F_{max}$  value is due to the fruit leather's plastic texture, which allows it to

roll easily and prevents it from breaking. Additionally, the addition of the hydrocolloid kappa-carrageenan increased the tensile strength, which may result in improved products (Chen et al., 2007). Our results were significantly greater than those of the blueberry fruit leather cultivars Blue Magic and Barlington, which had  $F_{max}$  values of 15.8 and 15.9 Newton, respectively (Karki, 2011). Additionally, it has a higher Newton value than pineapple leathers, ranging from 2.1 to 17.1 Newton (Phimpharian et al., 2011b).

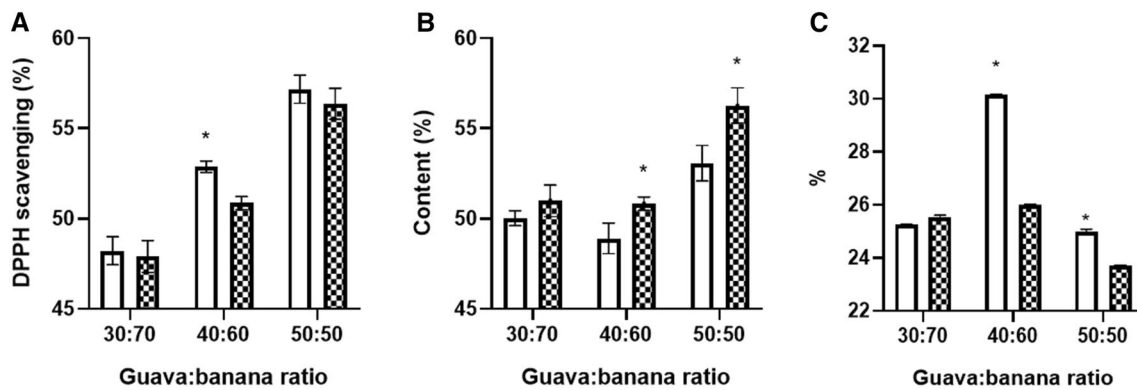
The heating process imparts the fruit leather's plasticity. The pectin and crude fibers in banana and guava raw material act as a gelling agent, absorbing water and hydrocolloids (gum Arabic and kappa-carrageenan) and forming a double helix like-structure. The gel strength and stability increase as the width of the double helix like-structure increases. Each of these processes increases the tensile strength of the material (Sundarraaj & Ranganathan, 2017).

### Effects of fruit ratio and hydrocolloids on functional properties

Guava and banana are loaded with antioxidant compounds such as polyphenols and flavonoids, as well as vitamins. Their abundance, however, may be diminished as a result of food processing (Minatel et al., 2017). It was discovered that hydrocolloids are capable of retaining functional compounds within food matrices (Munin & Edwards-Lévy, 2011). Thus, we determined antioxidant capacity by measuring the concentrations of DPPH and ascorbic acid (Frediansyah et al., 2021; Mohamed et al., 2018).

The DPPH of each formulated guava-banana fruit leather is depicted in Fig. 2A. DPPH values for kappa-carrageenan and gum Arabic were 48–57% and 48–56%, respectively. The DPPH values of kappa-carrageenan containing 40% guava and 60% banana were significantly higher ( $p < 0.05$ ) than those of gum Arabic. In this study, the antioxidant capacity of DPPH was determined to be between 47.91 and 57.18%. Figure 2A depicts the DPPH of each formulated guava-banana fruit leather. The DPPH values for kappa-carrageenan and gum Arabic were 48–57% and 48–56%, respectively. DPPH values of kappa-carrageenan containing 40% guava and 60% banana were significantly higher ( $p < 0.05$ ) than those of gum Arabic. The antioxidant capacity of DPPH was determined to be between 47.91 and 57.18 percent in this study. These percentages were lower than those found in persimmon fruit leather, which ranged from 83.53 to 87.08% (Mohamed et al., 2018) and lower than those found in kiwi fruit leather, which ranged from 81.21 to 88.37% (Barman et al., 2021). Banana has a low antioxidant capacity (Shian & Abdullah, 2012). Fruit leather containing 3% kappa-carrageenan and 3% gum Arabic exhibited no significant difference in DPPH activity. This is consistent





**Fig. 2** The DPPH scavenging activities (A); ascorbic acid content (B); and starch digestibility performance (C) of various formulations of guava-banana fruit leather. The white bar is encoded for kappa-carrageenan, the bar contains a black box for gum Arabic

with research on kiwi fruit leather made with xanthan gum, guar gum, and pectin (Barman et al., 2021). Therefore, the addition of 3% gum Arabic resulted in a negligible increase in comparison to the addition of 3% kappa-carrageenan. This is because gum Arabic has also been extensively reported to be a potent antioxidant. (Ali, 2004; Kaddam et al., 2017). Additionally, guava and banana puree contributed to the DPPH activity in our study. Therefore, it's unsurprising that banana-guava fruit leather exhibits less DPPH activity than persimmon or kiwi fruit leather. Additionally, the antioxidant content of the fruit leather product may be explained by the formation of Maillard browning pigments, which enhance the antioxidant activity of the product. (Delgado-Andrade et al., 2010).

Ascorbic acid content was significantly higher ( $p < 0.05$ ) in gum Arabic containing 40% guava and 60% banana and 50% guava and 50% banana, as shown in Fig. 2B. Ascorbic acid concentrations in this study ranged between 48.91 and 56.27%. These findings corroborated those obtained with papaya-soy fruit leather, which had a moisture content of 54.0 to 56.01% (Ghimire & Ojha, 2016). In general, when compared to kappa-carrageenan, gum Arabic significantly increased ascorbic acid. Due to the wall characteristics of gum Arabic, it has been reported to be effective at protecting ascorbic acid and suitable as a microencapsulation agent (Al-Ismail, El-Dijani, Al-Khatib, & Saleh, 2016; Righetto, Netto, & Agriculture, 2006). Scanning electron microscope was also used to demonstrate this effectiveness (Al-Ismail et al., 2016). Additionally, gum Arabic is a powerful antioxidant (Ali, 2004; Kaddam et al., 2017), which means it can also help protect vitamin C.

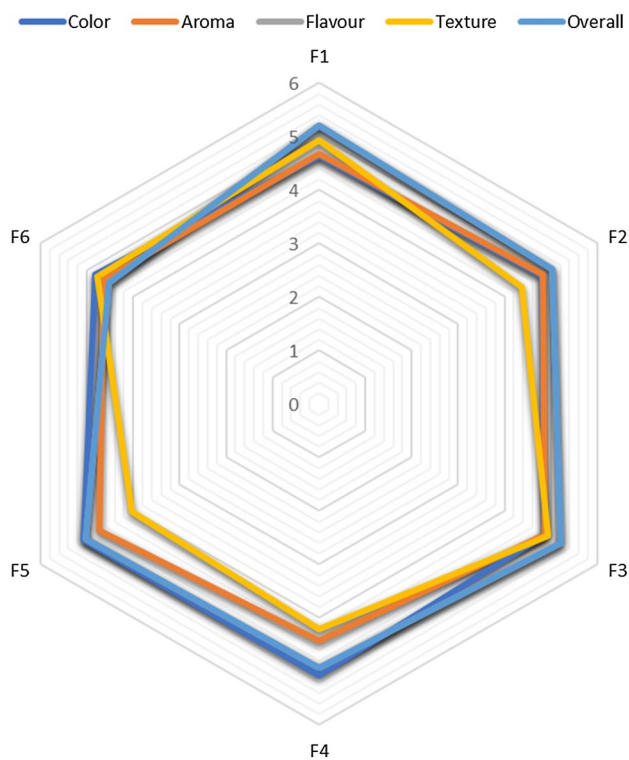
#### Effects of fruit ratio and hydrocolloids on starch digestibility

Figure 2C depicts the starch digestibility of guava-banana fruit leather. The fruit ratio and the addition of hydrocolloids

have a significant effect on the rate of digestion of guava-banana fruit leather starch. The digestibility of starch refers to how easily a particular type of starch can be hydrolyzed by enzymes that degrade starch into simpler units. Processing, the fat and protein content of foods, the fiber content of foods, the amylose and amylopectin content of foods, and the presence of antinutrients in food ingredients are all factors that can affect starch digestibility (Alvarenga, Aldrich, Shi, & Technology, 2021). Overall, the digestibility of starch in guava-banana fruit leather ranged from 24.98 to 30.15%. On Average, gum Arabic inhibited starch digestion in vitro significantly better ( $p < 0.05$ ) than the addition of kappa-carrageenan. This mechanism is caused by the formation of a physical barrier that limits the attack of digestion enzymes (Yi et al., 2015). The results showed that the addition of hydrocolloid gum Arabic could reduce starch digestibility or slow the rate of intestinal glucose absorption, which is beneficial for diabetics. Several studies support the effectiveness of gum Arabic in reducing starch digestibility (Bae et al., 2019; Wang, Ma, Gan, Lu, & Wang, 2021).

#### Effects of fruit ratio and hydrocolloids on sensory perception

When the hydrocolloid kappa-carrageenan was added to fruit leather made with a 50:50, 40:60, or 30:70 mixture of pureed guava and banana, the panellists expressed some fondness for the product (Fig. 3, overall). On the other hand, the inclusion of gum Arabic in all banana-guava ratios did not appear to excite the panellists. According to texture perception (Fig. 3), fruit leather's texture is perceived as neutral to favourable. When compared to gum Arabic, the hydrocolloid kappa-carrageenan, on the other hand, resulted in significantly higher acceptance in all guava-banana puree ratios (F1, F3, and F6). This result is consistent with the one obtained for tensile strength (Fig. 1C and Sect. 3.4). In all of these formulations, adding 0.3% hydrocolloid



**Fig. 3** Sensory perception analysis of various formulations of guava-banana fruit leather. F1 (also known as 50:50 (guava: banana) with kappa-carrageenan), F2 (also known as 50:50 (guava: banana) with gum Arabic), F3 (also known as 40:60 (guava: banana) with kappa-carrageenan), F4 (also known as 40:60 (guava: banana) with gum Arabic), F5 (also known as 30:70 (guava: banana) with gum Arabic), F6 (also known as 30:70 (guava: banana) with kappa-carrageenan)

kappa-carrageenan increases the tensile strength of guava-banana fruit leather. Thus, the tensile strength observed in our study can be ascribed to the plastic-like texture of the fruit leather. When bitten and chewed, the fruit leather should have a soft, plastic-like texture, indicating that it is soft and provides a chewing sensation. Fruit leather products should have a plastic texture to avoid snapping when pulled. It should be soft and chewy after biting and chewing, allowing it to be rolled around in the mouth.

The guava-banana fruit leather is well-accepted due to its colour, aroma, and flavour perception (Fig. 3). The addition of gum Arabic and kappa-carrageenan had no effect on the colour, aroma, or flavour of the guava-banana fruit leather product, as both are hydrocolloids that do not contain volatile ingredients that impart colour and aroma to food ingredients (Gujral et al., 2013). Banana flesh is yellow due to the presence of carotenoids (Setiaboma et al., 2019), while guava flesh is red due to the presence of lycopene (Nwai-chi et al., 2015). When bananas and guavas are combined, the resulting fruit leather products become yellow or red in colour as the guava content increases. Additionally, aroma is created by volatile components found in foods. Volatile

components, on the other hand, can be lost during processing, most notably through heat. However, kappa-carrageenan and gum Arabic lack volatile components and thus lack aroma. Moreover, as the hydrocolloid used in this study is flavourless. This guava-banana fruit leather produces a flavour that is nearly identical to the original, which is sweet and slightly sour. The sweetness comes from guava and bananas, which are naturally high in fructose, a type of fruit sugar. Meanwhile, the tart flavour is imparted by the organic acids found in bananas and guavas.

## Conclusion

Our findings indicate that adding 0.3% hydrocolloid kappa-carrageenan to guava-banana fruit leather improves its tensile strength, surface color, proximate content, antioxidant capacity via DPPH, and sensory characteristics. It was discovered that gum Arabic is more effective at retaining water activity and ascorbic acid levels, as well as improving starch digestibility. In general, the ratio of guava to banana had no discernible effect on any formulation. The sensory preferences of various formulations used to make guava-banana fruit leather were compared, and it was discovered that formulations containing kappa-carrageenan had the highest sensory preferences. In summary, supplementing guava-banana fruit leather with 0.3% hydrocolloid kappa carrageenan may improve its physicochemical and functional properties, as well as sensory perception. This work establishes the foundation for the industrialization of guava-banana fruit leather.

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