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Physicochemical and Organoleptic Characteristics of Coffee Husk (Coffea Arabica L.) Leather-Supplemented Pineapple and Carrageenan

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A B S T R A C T

Coffee husk is a by-product of coffee processing that contains carbohydrates, protein, fiber, and bioactive compounds; however, its utilization remains limited and is generally associated with low-value applications. Therefore, developing coffee husk into fruit leather is expected to provide an alternative strategy to increase the added value of this by-product while producing a value-added food product. This study aimed to determine the effect of pineapple addition and carrageenan concentration on the physicochemical, antioxidant, and organoleptic characteristics of coffee husk leather and to determine the best formulation. The study used a completely randomized design with a two-factor factorial arrangement and two replications. The first factor was pineapple addition at 20%, 30%, and 40% of the total formulation, while the second factor was carrageenan concentration at 0.6%, 0.8%, and 1.0%. The results showed that pineapple addition and carrageenan concentration significantly affected coffee husk leather characteristics. The best treatment was obtained from the formulation containing 40% pineapple and 1.0% carrageenan, which had a moisture content of 9.18%, reducing sugar content of 64.51%, vitamin C content of 53.15 mg/100 g, antioxidant activity of 71.13% inhibition based on the DPPH assay, crude fiber content of 21.95%, and tensile strength of 0.01554 N/mm². The organoleptic scores were 3.88 for color, 3.52 for taste, 3.56 for aroma, and 3.48 for texture, which were categorized as neutral. These findings indicate that the formulation of 40% pineapple and 1.0% carrageenan can be applied to improve the physicochemical and antioxidant characteristics of coffee husk leather, while supporting the valorization of coffee husk into a value-added food product.

Contribution to Sustainable Development Goals (SDGs):
SDG 6: Clean Water and Sanitation
SDG 11: Sustainable Cities and Communities
SDG 13: Climate Action

1. INTRODUCTION

1.1. Research Background

Global coffee consumption and production continue to increase, including Arabica coffee, a major commodity widely consumed globally. Increased coffee production also generates large amounts of solid waste, including coffee husks. Based on the processing method, coffee husks are divided into coffee pulp, produced through a wet process, and coffee husks, produced through a dry process [160. Coffee husks consist of the outer skin, pulp, and parchment and are generally used as fuel or fertilizer. However, coffee husks contain fiber, pectin, and bioactive compounds such as phenolics, caffeine, and tannins, which have the potential to be used as value-added food products [8].

One alternative use for coffee husks is processing them into coffee husk leather. Fruit leather is a sheet-shaped product made from fruit pulp or puree through a cooking and drying process. It has a chewy texture and can be consumed as a snack [8]. However, previous research reported that using 100% coffee husk pulp in leather production resulted in a less elastic product, and its taste and aroma were not yet acceptable to consumers [1]. This indicates that coffee husk pulp alone is insufficient to produce leather with desirable physical and sensory characteristics. Therefore, the addition of pectin from other sources is required to improve the elasticity of the leather, while additional ingredients that can provide a more acceptable flavor and aroma are also needed [1].

Pineapple can be used as an additional ingredient because it contains pectin while also providing a sweet-sour flavor, distinctive aroma, and vitamin C, potentially improving the taste, aroma, and texture of coffee husk leather. Furthermore, carrageenan is added as a hydrocolloid that can form a gel, thicken, and stabilize the product structure, thus increasing the flexibility and elasticity of the leather [12].

Therefore, the combination of coffee husk, pineapple, carrageenan, and sugar has the potential to produce coffee husk leather with better physical, sensory, and functional characteristics. Sugar not only acts as a sweetener but also helps form a gel structure with the pectin and carrageenan [22]. This product development is expected to increase the added value of coffee husk as an agro-industrial byproduct, reduce the potential for environmental pollution from waste accumulation, and produce a practical snack alternative with potential fiber and bioactive compounds. Therefore, utilizing coffee husk as fruit leather can support the concept of sustainable food processing while increasing the economic value of coffee industry byproducts.

1.2. Literature Review

Coffee (*Coffea sp.*) is an important agricultural commodity, particularly *Coffea arabica* and *Coffea canephora* var. *robusta*. Coffee processing through wet and dry methods produces different by-products, namely *coffee pulp* and *coffee husk*. *Coffee husk*, produced through the dry process, consists of the outer skin, pulp, and parchment and accounts for approximately 12% of the coffee fruit on a dry basis [22]. Although it has been utilized as cascara and other non-food products, *coffee husk* contains various bioactive compounds, including polyphenols and phenolics such as chlorogenic acid, epicatechin, catechin, and ferulic acid, which contribute to antioxidant and antimicrobial activities [20]. However, the composition and concentration of these compounds may vary depending on coffee species, cultivar, cultivation conditions, and processing methods [25]. Therefore, *coffee husk*, particularly from Arabica coffee with its relatively complex aroma and acidity, has potential to be developed into a value-added food ingredient [25].

Despite its potential nutritional and bioactive properties, the direct utilization of *coffee husk* as a food ingredient remains challenging. The high fiber content and relatively coarse structure may negatively affect product texture, while the presence of compounds such as caffeine, tannins, and phenolics may contribute to bitterness and astringency [20]. In addition, previous studies reported that using 100% coffee husk pulp for leather production resulted in a less elastic texture and sensory characteristics, particularly taste and aroma, that consumers had not yet fully accepted [1]. These findings indicate that *coffee husk* requires formulation with additional ingredients to improve its physical structure and sensory acceptability. Therefore, the selection of fruits and hydrocolloids that can contribute pectin, desirable flavor, and improved gel structure is important for developing acceptable *coffee husk*-based food products.

Fruit leather is a dried fruit purée product formed into thin, elastic, and rollable sheets, generally with a moisture content of approximately 10–20% [1]. The quality of *fruit leather* is influenced by the composition of raw materials and processing conditions, particularly heating and drying. Pectin and fiber are important components because they contribute to gel formation, texture, and elasticity, while moisture content affects texture, flexibility, and shelf life [22]. However, the contribution of fiber to the product structure differs from that of pectin. Although fiber can increase structural density, excessive fiber may result in a rougher and less flexible texture, whereas pectin contributes more directly to the formation of a continuous gel network [3]. Controlled heating and drying are therefore necessary to obtain an appropriate product structure while minimizing degradation of heat-sensitive bioactive compounds, including vitamin C and phenolic compounds [11]. Thus, the development of *coffee husk leather* requires a balance between the retention of nutritional and bioactive components and the formation of desirable mechanical and sensory properties..

Pineapple (*Ananas comosus* L.) is a suitable fruit for developing *coffee husk leather* because it contains fiber, pectin, organic acids, vitamin C, flavonoids, and bromelain [7]. These components can contribute to the nutritional, functional, and sensory characteristics of the product [23]. Pineapple contains approximately 0.5 g of pectin per 100 g, making it useful for improving the structure and elasticity of *fruit leather* [18]. In addition to its structural role, pineapple provides a characteristic sweet-acidic flavor and aroma that may help reduce the less desirable sensory characteristics associated with *coffee husk* [1]. However, the effects of pineapple depend on its concentration and maturity. An increased pineapple proportion may improve flavor, vitamin C content, and moisture, but excessive addition may also increase acidity and modify the balance between sweetness and sourness [17]. Therefore, optimization of pineapple concentration is necessary to obtain a product with desirable physicochemical and sensory characteristics.

Carrageenan can be used as a hydrocolloid to strengthen the structure of *coffee husk leather*. It is a polysaccharide extracted from red seaweeds such as *Kappaphycus alvarezii* and *Eucheuma denticulatum*. Its hydrophilic properties allow it to bind water and form a three-dimensional gel network, thereby contributing to texture, elasticity, and mechanical strength [6]. Kappa carrageenan is particularly effective in producing strong gels, with gel formation influenced by carrageenan concentration, temperature, and the presence of ions such as K^+ and Ca^{2+} [10].

Previous studies have shown that increasing carrageenan concentration can improve gel strength and product structure. However, the relationship is not always linear, as excessive carrageenan may produce an overly rigid texture, reduce flexibility, and promote syneresis [2]. This indicates that carrageenan concentration must be optimized according to the characteristics of the food matrix. In *coffee husk leather*, carrageenan is expected to interact with the pectin provided by pineapple and the fiber contained in *coffee husk* to form a more stable structure. Nevertheless, limited information is available regarding the combined effects of pineapple and carrageenan on the mechanical properties of *coffee husk leather*.

Previous studies have demonstrated the potential of *coffee husk* as a source of fiber and bioactive compounds, while pineapple and carrageenan have separately been used to improve the quality of *fruit leather* and other food products. However,

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previous findings also indicate that the use of 100% *coffee husk* pulp can result in a product with insufficient elasticity and less acceptable taste and aroma [1]. Although pineapple may provide pectin and improve sensory characteristics, and carrageenan can strengthen the gel structure, studies evaluating the combined effects of pineapple concentration and carrageenan concentration on *coffee husk leather* remain limited. In particular, the interaction between these two ingredients in relation to physicochemical properties, antioxidant activity, mechanical strength, and sensory characteristics has not been sufficiently investigated.

Therefore, the novelty of this study lies in the development and optimization of *coffee husk leather* through the combined use of pineapple as a natural source of pectin and flavor-modifying ingredient and carrageenan as a hydrocolloid to improve the product structure. This study aimed to determine the effects of pineapple addition and carrageenan concentration on the physicochemical, antioxidant, mechanical, and sensory characteristics of *coffee husk leather*, and to identify the best formulation with desirable overall product characteristics.

1.3. Research Objective

This study aims to analyze the effect of adding pineapple pulp and carrageenan on the physicochemical properties of the resulting coffee husk leather, and to determine the most preferred treatment combination.

2. MATERIALS AND METHODS

2.1. Research Location and Time

This research was conducted in the Food Processing Technology Laboratory, Food Analysis Laboratory, and Sensory Testing Laboratory of the Food Technology Study Program, UPN "Veteran" East Java. This research was conducted since January 2026.

2.2. Experimental Design

This study used a factorial Completely Randomized Design (CRD) consisting of two treatment factors. Factor I: Addition of pineapple pulp (A), consisting of three levels: A1 (20%), A2 (30%), and A3 (40%). Factor II: Carrageenan concentration (B), consisting of three levels: B1 (0.6%), B2 (0.8%), and B3 (1.0%).

2.3. Coffee Husk Leather Preparation

The production of coffee husk leather begins by mixing 300g of coffee husk pulp and pineapple pulp with a ratio of 20% (A1), 30% (A2), and 40% (A3) (w/w), then adding 30% sugar and carrageenan with a concentration of 0.6%, 0.8%, or 1.0%. The mixture is stirred until homogeneous, and pH analysis is performed. Next, the mixture is heated at 70°C for ±3 minutes to form a suitable dough, then molded with a thickness of ±2–3 mm. The molded dough is then dried using a cabinet dryer at 70°C for ±7 hours until a dry sheet is obtained. The sheet is then cut into 5 × 5 cm sizes and rolled to obtain coffee husk leather products. The final product is then analyzed including water content, crude fiber content, reducing sugar content, antioxidant activity, vitamin C content, tensile strength, and organoleptic tests including taste, color, aroma, and texture.

2.4. Data Analyze

The main effects of pineapple, carrageenan, and the interaction of pineapple and carrageenan per parameter will be analyzed using Analysis of Variance (ANOVA). If a significant interaction effect was observed ($p < 0.05$), Duncan's Multiple Range Test (DMRT) was performed at a 5% significance level. The best treatment was comprehensively determined using the De Garmo Effectiveness Index.

3. RESULT AND DISCUSSION

3.1. Chemical Analysis

Table 1. Average Chemical Analysis of Coffee Husk Leather with Pineapple Addition Treatment and Carrageenan Concentration

Treatment		pH	Moisture Content (%)	Crude Fiber Content (%)	Reduced Sugar Content (%)	Antioxydant Activity (%)	Vitamin C mg/100g
Pineapple	Carrageenan						
20%	0.6%	3.46±0.02	18.55%^{a} ± 0.31	14.20%^{a} ± 0.14	31.45%^{a} ± 0.00	24.60%^{g} ± 0.90	25.05^{a} ± 0.00
20%	0.8%	3.52±0.02	18.02%^{a} ± 0.14	15.12%^{b} ± 0.10	33.69%^{b} ± 0.00	35.75%^{f} ± 1.25	32.4^{c} ± 0.00
20%	1.0%	3.66±0.05	16.21%^{b} ± 0.15	16.10%^{c} ± 0.14	36.48%^{c} ± 0.00	39.52%^{e} ± 1.11	35.3^{c} ± 0.00
30%	0.6%	3.24±0.03	15.47%^{c} ± 0.24	16.27%^{c} ± 0.10	41.39%^{d} ± 0.00	34.80%^{f} ± 1.03	26.35^{ab}± 0.01
30%	0.8%	3.4±0.02	14.62%^{d} ± 0.31	16.77%d ± 0.10	46.44%^{e} ± 0.01	46.22%^{d} ± 1.51	32.65^{c} ± 0.00
30%	1.0%	3.57±0.01	13.28%^{e} ± 0.22	17.27%^{e} ± 0.10	47.02%^{e} ± 0.00	54.56%^{c} ± 0.80	40.4^{d} ± 0.00
40%	0.6%	3.18±0.05	12.76%^{e} ± 0.30	20.45%^{f} ± 0.14	51.81%^{f} ± 0.01	49.79%^{e} ± 11.8	27.6^{b} ± 0.00
40%	0.8%	3.27±0.01	12.00%^{f} ± 0.25	21.02%^{g} ± 0.10	55.54%^{g} ± 0.00	59.34%^{b} ± 1.67	46.75^{e} ± 0.01
40%	1.0%	3.4±0.05	9.18%^{g} ± 0.58	21.95%^{h} ± 0.14	64.51%^{h} ± 0.00	71.13%^{a} ± 1.81	53.15^{f} ± 0.00

3.1.1. pH

Based on the results of the analysis of variance, it shows that there is no significant interaction ($p>0.05$) between the treatment of adding pineapple and the concentration of carrageenan on the pH of coffee husk leather, however, each treatment has a significant effect on the pH of coffee husk leather. The average pH value of coffee husk leather with the treatment of adding pineapple and the concentration of carrageenan on the pH of coffee husk leather can be seen in Table 1.

The addition of sugar at the same concentration in each treatment did not affect the difference in pH of *coffee husk leather*, so the pH change was mainly influenced by the addition of pineapple pulp and carrageenan concentration. The higher the addition of pineapple pulp, the pH of *leather* decreased because the pH of pineapple pulp was lower than that of *coffee husk* pulp. Conversely, increasing the concentration of carrageenan tended to increase the pH because carrageenan is basic with a pH of 9–10, and increasing the proportion of solids so that the relative concentration of organic acids and H^+ ions decreased [5][12]. Although the addition of pineapple and carrageenan concentration made a significant difference in pH, all treatments were still in the optimal pH range of 3–4 for gel formation, so that the resulting *coffee husk leather* had good gel formation [22].

3.1.2. Moisture Content

The analysis of variance showed a significant interaction ($p \leq 0.05$) between pineapple addition and carrageenan concentration on the moisture content of coffee husk leather, with each treatment significantly affecting the moisture content. The average moisture content of coffee husk leather by pineapple addition and carrageenan concentration is shown in Table 1.

The table shows that the higher the addition of pineapple and carrageenan, the lower the water content of coffee husk leather. The addition of pineapple increases the fiber content which has free hydroxyl groups that are polar so that it can bind water and increase the total solids of the product [15]. In addition, increasing the concentration of carrageenan as a hydrocolloid causes the formation of a denser three-dimensional gel network through interactions between polymer chains. This network binds and limits the mobility of water in the product matrix, making it more difficult for water to move during the drying process and ultimately resulting in a lower water content [6][19].

3.1.3. Crude Fiber Content

The analysis of variance showed a significant interaction ($p \leq 0.05$) between pineapple addition and carrageenan concentration on the crude fiber content of coffee husk leather, with each treatment significantly affecting the crude fiber content. The average crude fiber content of coffee husk leather by pineapple addition and carrageenan concentration is shown in Table 1.

The table shows that the higher the addition of pineapple and the higher the carrageenan, the higher the crude fiber content of coffee husk leather. This is because pineapple contains fiber, such as cellulose and hemicellulose, which contribute to the fiber content of the product [21], while carrageenan acts as a stabilizing hydrocolloid which is a source of fiber from the water-soluble polysaccharide group, so that an increase in crude fiber will occur due to the increasing amount of carrageenan [26]. In addition, the decrease in water content during drying causes the solid components, including fiber, to become more concentrated so that the measured crude fiber content increases [22].

3.1.4. Reduced Sugar Content

Analysis of variance showed a significant interaction ($p \leq 0.05$) between pineapple addition and carrageenan concentration on the reducing sugar content of coffee husk leather, with each treatment significantly affecting reducing sugar content. Table 1 shows the average reducing sugar content of coffee husk leather by pineapple addition and carrageenan concentration.

The table shows that higher pineapple and carrageenan content increases the reducing sugar content of coffee husk leather. This is because pineapple contains glucose and fructose, which are reducing sugars. Therefore, the higher the pineapple content, the greater the source of reducing sugar in the formulation [21]. The high reducing sugar content is due to the inversion process of sucrose into invert sugar (glucose and fructose). The inversion process can be affected by reactions with acid, heat, and mineral content [15] The higher the pineapple and carrageenan content, the lower the water content, resulting in a more concentrated and increased reducing sugar content [21].

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3.1.5. Antioxidant Activity

The analysis of variance showed a significant interaction ($p \leq 0.05$) between pineapple addition and carrageenan concentration on the antioxidant activity of coffee husk leather, with each treatment significantly affecting the antioxidant activity of coffee husk leather. The average antioxidant activity values of coffee husk leather with pineapple and carrageenan addition are shown in Table 1.

The table shows that the higher the addition of pineapple and carrageenan concentration, the higher the antioxidant activity of coffee husk leather. This is thought to be due to pineapple's high antioxidant activity, which is 79.65% (Table 1). However, the product's antioxidant activity decreased significantly compared to the raw material due to oxidation of antioxidant compounds during preparation and processing due to exposure to water, light, air, and heat [18]. The addition of carrageenan can help maintain antioxidant compounds due to its properties as a hydrocolloid that binds water and forms a three-dimensional network, thus protecting bioactive compounds during heating [15]. Furthermore, the decrease in water content during drying causes bioactive compounds to become more concentrated and phenolic compounds to be more easily extracted, thus increasing measurable antioxidant activity [18].

3.1.6. Vitamin C

The analysis of variance showed a significant interaction ($p \leq 0.05$) between pineapple addition and carrageenan concentration on the vitamin C content of coffee husk leather, and each treatment significantly affected the vitamin C content. The average vitamin C content of coffee husk leather by pineapple addition and carrageenan concentration is shown in Table 1.

The table shows that the higher the pineapple addition and carrageenan concentration, the higher the vitamin C content of coffee husk leather. This increase is because pineapple is a source of vitamin C, so the greater the proportion of pineapple added, the greater the contribution of vitamin C to the product. Carrageenan can also help retain vitamin C because it forms a three-dimensional gel matrix that protects bioactive compounds during heating [15]. In addition, water evaporation during drying concentrates the vitamin C retained in the product matrix per 100 g of product. However, vitamin C content still decreases compared with the initial raw material because some vitamin C degrades due to heating, drying, and oxidation during processing [15].

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3.2. Physical Analysis

Table 2. Average Physical Analysis of Coffee Husk Leather with Pineapple Addition Treatment and Carrageenan Concentration

Treatment		Tensile Strength (N/mm^2)	Color		
Pineapple	Carrageenan		Lightness (L*)	Redness (a*)	Yellowness (b*)
20%	0.6%	0.00816 ± 0.00	45.70^{a}	-7.37^{a}	0.81^{ab}
20%	0.8%	0.00913 ± 0.00	44.25^{b}	-7.52^{a}	0.91^{a}
20%	1.0%	0.01028 ± 0.00	41.35^{d}	-7.12^{ab}	1.06^{abc}
30%	0.6%	0.01011 ± 0.00	42.55^{c}	-6.97^{abc}	1.16^{abc}
30%	0.8%	0.01135 ± 0.00	41.00^{d}	-7.07^{ab}	1.16^{abc}
30%	1.0%	0.01274 ± 0.00	40.55^{de}	-7.12^{ab}	1.41^{bcd}
40%	0.6%	0.01212 ± 0.00	40.75^{de}	-6.47^{bc}	1.46^{cd}
40%	0.8%	0.01381 ± 0.00	40.50^{de}	-6.27^{c}	1.86^{d}
40%	1.0%	0.01554 ± 0.00	39.95^{e}	-6.32^{c}	1.91^{d}

3.2.1. Tensile Strength

The analysis of variance showed a significant interaction ($p \leq 0.05$) between pineapple addition and carrageenan concentration on the tensile strength of coffee husk leather, with each treatment significantly affecting the tensile strength. Table 2 shows the average tensile strength values for coffee husk leather with pineapple addition and carrageenan concentration.

The table shows that higher pineapple and carrageenan concentrations increase the tensile strength of coffee husk leather. This is due to the interaction between pineapple pectin and carrageenan, which forms a denser, more compact gel network and increases the product's mechanical strength [4]. Furthermore, the decrease in water content from increased carrageenan also strengthens the gel structure, making the product more resistant to tensile forces and less prone to deformation [21].

3.2.2. Color

The analysis of variance showed a significant interaction ($p \leq 0.05$) between pineapple addition and carrageenan concentration on the lightness (L*) of coffee husk leather. However, there was no significant interaction on the redness (a*) and yellowness (b*) of coffee husk leather. However, pineapple addition significantly affected the yellowness (b*). The average color values of coffee husk leather with pineapple addition and carrageenan concentration are shown in Table 2.

Based on Table 8, increasing the addition of pineapple and carrageenan concentration causes the L* value to decrease so that *coffee husk leather* becomes darker due to the increase in total solids and non-enzymatic browning reactions during cooking and drying [22]. The a* and b* values are only affected by the addition of pineapple, with an increase in a* towards zero indicating a decrease in green color intensity, while an increase in b* indicates a stronger yellow color due to the carotenoid pigment content in pineapple [21]. Carrageenan does not have a significant effect on a* and b* because it does not have pigment, so color changes are mainly determined by the proportion of pineapple and the processing process [4].

3.3. Organoleptic Test (Hedonic Test)

Organoleptic evaluation consisted of a hedonic test (preference test using a five-point scale: 1 = strongly dislike, 2 = dislike, 3 = slightly like, 4 = like, and 5 = strongly like) with 25 panelists to assess specific quality attributes. The evaluated attributes included taste, color, texture, and aroma. Semi-trained panelists provided spontaneous evaluations based on mouthfeel and visual appearance.

Table 3. Average Organoleptic Test of Coffee Husk Leather with Pineapple Addition Treatment and Carrageenan Concentration

Treatment		Color		Texture		Aroma		Taste	
Pineapple	Carrageenan	Average	Number of Rankings	Average	Number of Rankings	Average	Number of Rankings	Average	Number of Rangkings
20%	0.6%	3.20	107.5	2.52	77	3.24	120.5	3.04	99.5
20%	0.8%	3.40	123	3.44	130.5	3.12	111.5	3.32	118.5
20%	1.0%	3.48	133	3.16	110	2.96	111.5	3.16	103.5
30%	0.6%	2.92	93.5	3.20	117.5	3.20	124.5	3.48	135
30%	0.8%	3.36	125.5	3.48	135.5	3.64	147.5	3.96	158.5
30%	1.0%	3.84	164	3.68	147	3.40	132	3.44	126.5
40%	0.6%	2.84	94.5	3.64	144	3.04	114.5	3.24	115.5
40%	0.8%	3.36	122	3.08	111.5	3.28	125.5	3.40	124
40%	1.0%	3.88	164	3.48	134	3.56	140	3.52	135

3.3.1. Color

The Friedman test showed that the addition of pineapple and carrageenan concentration significantly affected the color of coffee husk leather x count (24.6275) > x^2 table (5.991). The average color preference scores for coffee husk leather based on the treatments are shown in Table 3.

Based on Table 9, the panelists' preference level for the color of *coffee husk leather* ranged from 2.84–3.88. The treatment of 40% pineapple and 1.0% carrageenan was the most preferred because it produced a bright and shiny brown color, while 40% pineapple and 0.6% carrageenan had the lowest preference level. The color of the product is influenced by the Maillard reaction between reducing sugars and proteins during heating, while the addition of pineapple helps brighten the brown color of *coffee husk* through its yellow pigment [14]. Carrageenan also forms a more homogeneous gel matrix, making the product surface look glossier and more attractive [21].

3.3.2. Texture

The Friedman test showed that the addition of pineapple and carrageenan concentration significantly affected the texture of coffee husk leather, with x count (19.17) > x^2 table (5.991). Table 3 shows the average texture preference scores for coffee husk leather based on the treatments.

Based on Table 3, the panellists' preference for the texture of *coffee husk leather* ranged from 2.52–3.68, with 30% pineapple and 1.0% carrageenan being the most preferred treatment because it produced a soft, slightly mushy, and non-sticky texture. Pineapple pectin interacts with carrageenan to form a plastic and flexible texture [5]. Adding 20% pineapple resulted in a harder texture due to low pectin, while 40% tended to be softer and stickier due to higher water content. Too high a concentration of carrageenan can also produce a gel that is too strong and stiff, so a balance of pectin, fiber, water content, and carrageenan is needed to obtain the most preferred texture [9].

3.3.3. Aroma

The Friedman test showed that the addition of pineapple and carrageenan concentration did not significantly affect the aroma of coffee husk leather x count (5.34) < x^2 table (5.991). Table 3 shows the average aroma preference scores for coffee husk leather by treatment.

Based on Table 3, the panelists' preference level for the aroma of *coffee husk leather* ranged from 2.96–3.64, with the treatment of 30% pineapple and 0.8% carrageenan being the most preferred, while pineapple 20% and 1.0% carrageenan were the least preferred. The product aroma was dominated by coffee, pineapple, and sweet sugar/caramel. The addition of pineapple, carrageenan, and sucrose did not have a significant effect on the aroma because carrageenan does not have a distinctive aroma and sucrose only acts as a sweetener, while the volatile compounds from pineapple and *coffee husk* partially evaporated during cooking and drying, so the aroma between treatments was relatively uniform [12].

3.3.4. Taste

The Friedman test showed that the addition of pineapple and carrageenan concentration did not significantly affect the taste of coffee husk leather x count (12.8525) > x^2 table (5.991). Table 3 shows the average taste preference scores for coffee husk leather by treatment. Based on Table 3, the panelists' preference for the taste of *coffee husk leather* ranged from 3.04–3.96, with the treatment of 30% pineapple and 0.8% carrageenan being the most preferred, while the treatment of 20% pineapple and 0.6% carrageenan was the least. All treatments tended to taste sweet because they included 30% sucrose, which also helped mask the astringent or bitter taste of *coffee husk* [15]. Adding pineapple and carrageenan did not significantly affect taste because the differences were relatively small, while 0.8% carrageenan produced a more compact structure and improved taste acceptance. In addition, the balance of sucrose sweetness, pineapple sourness, and the characteristics of *coffee husk* produced a relatively uniform taste across treatments [5][12].

3.4. *Determination of the Best Treatment Using the De Garmo Effectiveness Index*

The best treatment for coffee husk leather was determined using the De Garmo et al. (1984) effectiveness index for physicochemical and organoleptic characteristics. The best treatment was determined by weighting parameters based on their influence on coffee husk leather quality, then ranking the parameters by importance. Moisture content and pH are quality parameters where lower is better, because low moisture content supports product stability and shelf life, while low pH relates to the product's acidity. Conversely, crude fiber content, reducing sugar content, antioxidant activity, vitamin C, and color value are determined with a quality direction where the higher the better. The highest weight was given to the parameters of moisture content and crude fiber content because they are considered to have the most influence on the quality and main characteristics of coffee husk leather, while the lowest weight was given to the organoleptic parameters of aroma and vitamin C. The treatment with the addition of 40% pineapple and 1% carrageenan obtained the highest total effectiveness value, namely 9.19, and was therefore determined as the best treatment.

Table 13. Physicochemical and Organoleptic Properties of the Best Sample

Treatment	Results
Moisture Content (%)	9.18
Reduced Sugar Content (%)	64.51
Crude Fiber Content (%)	21.95
Antioxidant Activity (%)	71.13
Vitamin C (mg/100g)	53.15
Tensile Strenght (N/mm^2)	0.01554
Color	39.95(L*), -6.32(a*), 1.91(b*)
Organoleptic Color, Taste, Aroma, Texture	3.88; 3.52; 3,56; 3.48

Treatment with 40% pineapple and 1% carrageenan produced coffee husk leather with a water content of 9.18%, high antioxidant and fiber activity, and vitamin C of 53.15 mg/100 g. The tensile strength value of 0.01554 N/mm² indicated a compact and flexible product structure, while good organoleptic acceptance was indicated by a color value of 3.88, a taste of 3.52, an aroma of 3.56, and a texture of 3.48. The 40% pineapple and 1.0% carrageenan formulation was identified as the most optimal overall based on the De Garmo effectiveness index, although it did not achieve the highest score for each individual sensory attribute. These results indicate that the combination of 40% pineapple and 1% carrageenan can produce coffee husk leather with functional value and is acceptable as a coffee husk-based snack product, although shelf-life testing is needed to ensure product stability and viability before commercial development.

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4. CONCLUSION

There is a significant interaction between the addition of pineapple and carrageenan on water content, crude fiber content, reducing sugar content, antioxidant activity, vitamin C content, tensile strength, and lightness (L*), but there is no interaction on redness (a*) and yellowness (b*) of coffee husk leather. Furthermore, increasing the addition of pineapple and carrageenan tends to decrease water content, increase crude fiber, reducing sugar, antioxidant activity, vitamin C, and tensile strength, and affect the color and texture characteristics of the product. The best treatment for coffee husk leather is adding 40% pineapple and 1.0% carrageenan.

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