JOURNAL OF CHEMICAL PROCESS ENGINEERING
p-ISSN : 2527-4457
e-ISSN : 2655-2957

Vol. 8 No. 2 (2023)

Research Paper

Circular Economy-based Food Technology: Enhancing Red Dragon Fruit Jam Quality according to SNI 3746-2008

Inovasi Pangan Berbasis Ekonomi Sirkular: Peningkatan Kualitas Selai Buah Naga Merah sesuai SNI 3746-2008

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Artikel Histori : Submitted 13 October 2023, **Revised** 28 October 2023, **Accepted** 22 November 2023, **Online** 30 November 2023
https://doi.org/10.33096/jcpe.v8i2.882

ABSTRACT*:* Circular economy-based food technology innovation plays important role in overcoming environmental and sustainability challenges. This study aims to improve the quality of red dragon fruit (Hylocereus polyrhizus) jam by adding its peel, in line with SNI 3746-2008. The study will also explore the application of circular economy principles in the jam production process. This research uses both quantitative and qualitative methods, including Total Plate Count tests, organoleptic tests (condition and hedonic), fibre tests, moisture content tests, and literature reviews. The research results show that the addition of red dragon fruit peel improves the quality of the jam, with a Total Plate Count that meets standards, making it safe for consumption at $3.6x10^2$ Colony/g. Three parameters typically state the organoleptic acceptance level for condition tests as normal: colour (97%), odor (65%), and taste (74%). The hedonic test showed that the panelists liked the colour of the jam (7) and somewhat liked the odor and taste of the jam (6). The addition of red dragon fruit peel confirmed the positive fibre content. However, the panelists slightly disliked the jam's texture (4) due to its high moisture content (48.6%), indicating the need for improvement. From a circular economy perspective, this contributes to reducing biomass waste, utilising resources efficiently, increasing the added value of products, and providing a positive social and economic impact. This research's limitations include variations in raw material formulation that affect the final results, as well as the need for further studies to optimise moisture content and improve organoleptic test results.

Keywords: Red dragon fruit; Red dragon fruit peel; Fruit jam; Jam quality; SNI 3746-2008

ABSTRAK: *Inovasi teknologi pangan berbasis ekonomi sirkular berperan penting dalam mengatasi tantangan lingkungan dan keberlanjutan. Penelitian ini bertujuan meningkatkan kualitas selai buah naga merah (Hylocereus polyrhizus) melalui penambahan kulit buahnya sesuai SNI 3746-2008, serta mempelajari penerapan prinsip ekonomi sirkular dalam produksinya. Penelitian ini menggunakan metode kuantitatif dan kualitatif, meliputi uji Angka Lempeng Total, uji organoleptik (keadaan dan hedonik), uji serat, dan uji kadar air, serta studi pustaka untuk mendokumentasikan penerapan ekonomi sirkular. Hasil penelitian menunjukkan bahwa penambahan kulit buah naga merah meningkatkan kualitas selai, dengan Angka Lempeng Total yang memenuhi standar sehingga aman untuk dikonsumsi sebesar $3,6x10^2$ Koloni/g. Tingkat penerimaan organoleptik untuk uji keadaan umumnya menyatakan normal pada tiga parameter: warna (97%), aroma (65%), dan rasa (74%). Uji hedonik menunjukkan panelis menyukai warna selai (7) dan agak menyukai aroma serta rasa selai (6). Kandungan serat terkonfirmasi positif dengan penambahan kulit buah naga merah. Namun, kadar air selai perlu diperbaiki karena masih tinggi sebesar 48,6%, sesuai dengan hasil uji hedonik di mana tekstur selai agak tidak disukai (4) oleh panelis. Dari segi ekonomi sirkular, penelitian ini berkontribusi pada pengurangan limbah biomassa, pemanfaatan sumber daya secara efisien, peningkatan nilai tambah produk, serta memberikan dampak positif pada sosial dan ekonomi. Keterbatasan penelitian ini mencakup variasi formulasi bahan baku yang mempengaruhi hasil akhir, serta kebutuhan studi lebih lanjut untuk mengoptimalkan kadar air dan peningkatan hasil uji organoleptik.*

Kata Kunci*: Buah naga merah; Kulit buah naga merah; Selai buah; Kualitas selai; SNI 3746-2008*

1. INTRODUCTION

The modern food industry faces major challenges in its efforts to reduce biomass waste and increase the sustainability of production processes. The food industry generates large amounts of biomass waste to meet

Published by
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increasing consumer demand, including agricultural biomass waste [1], plantations [2], forestry [3], livestock [4], seafood [5], the food processing industry [6], and organic biomass waste in households [7]. Inadequate management can lead to detrimental effects on the environment, such as water [8], soil [9], and air [10] pollution, as well as health issues for humans. Indonesia often produces red dragon fruit peel as a type of biomass waste, particularly during the fruit harvest season [11]. Red dragon fruit is increasingly popular among consumers because of its unique taste and health benefits. However, people typically discard dragon fruit peels, leading to significant waste. The suboptimal management of dragon fruit peel waste should be addressed in more effective and innovative ways to alleviate the environmental burden. As a result, technological innovation that focuses on converting biomass waste into value-added products is essential to overcome this problem and support the food industry's sustainability.

Fruit jam is a food product that can be made using the peel and flesh of red dragon fruit. This product has an attractive taste and colour, as well as a high nutritional content that is beneficial for health and the environment. This is expected to increase the attractiveness of these jam products in the eyes of consumers, who are increasingly concerned about health and the environment. Researchers have conducted numerous studies on jam production, including various methods such as combining 100% red dragon fruit flesh [12][13][14][15][16], blending the flesh and peel of red dragon fruit [17][18], combining 100% red dragon fruit peel [19][20][21], blending red dragon fruit flesh with other fruits like soursop fruit [22], and blending red dragon fruit peel with other fruit flesh like pineapple [23], and tamarillo [24]. According to these various studies, researchers are interested in focusing on developing red dragon fruit jam using dragon fruit peel waste, which offers many benefits.

Dragon fruit peel contains bioactive compounds that are very beneficial for health. Dragon fruit peel is rich in anthocyanins, fibre, and antioxidants [25], which can play an important role in increasing the nutritional value of food products. Anthocyanins, for example, are known to have anti-inflammatory and antioxidant properties that can help protect the body from various chronic diseases, such as cancer and diabetes [26]. The fibre content in dragon fruit peel is also important for digestive health and can help control blood sugar levels and blood pressure [27]. The benefits of dragon fruit peel extend beyond its nutritional value. The anthocyanins in dragon fruit peel provide an attractive dark red pigment [28], which can improve the visual appearance of food products such as jam. The antioxidants in dragon fruit peel also function to extend the product's shelf life by preventing oxidation, which can damage product quality [29]. In addition, the high fibre content in dragon fruit peel can add texture and density to food products [30], making them more attractive to consumers who are looking for products that are not only delicious but also healthy.

Utilising dragon fruit peels can bring a number of advantages. From an environmental aspect, employing this waste can reduce the amount of organic waste generated by the fruit processing sector. This process is consistent with the concepts of the circular economy, which emphasise the reuse and recycling of materials to produce a more efficient and sustainable production system [31]. The manufacture of this dragon jam is environmentally friendly because it produces no waste and uses both the fruit's flesh and peel, guaranteeing that the environment remains zero waste [32]. Economically speaking, dragon fruit peel, previously regarded as useless, can now be used to create items with increased value. The economic value of red dragon fruit jam is also quite beneficial for agriculture displayed resilience during the COVID-19 epidemic by successfully transitioning to a circular economy paradigm [33]. Furthermore, the use of dragon fruit peel improves the efficiency of the jam product cycle, ensuring that no portion of the red dragon fruit is lost [34].

Red dragon fruit jam with the addition of its peel, must meet the quality standards set by the Indonesian National Standard (SNI) 3746-2008 [35] as can be observed in Tabel 1. The standard outlines a range of requirements for jam products, encompassing safety, taste, texture, and overall jam quality. By following SNI standards, this research aims to ensure that the proposed innovation not only improves product quality but also maintains safety and compliance with applicable regulations. The research method will entail processing the peel and flesh of red dragon fruit into a form suitable for incorporation into the jam-making process, such as

porridge. The jam formulations used are tested, including organoleptic analysis, jam quality tests, and microbiological tests, to ensure that the resulting jam is not only delicious and nutritious but also safe for consumption.

No.	Test Criteria	Unit	Regulations
1	Condition		
	Odor	-	Normal
	Colour	-	Normal
	Taste	-	Normal
2	Fruit Fiber	-	Positive
3	Dissolved Solids	% mass fraction	Min. 65
4	Microbial Contamination		
	Total Plate Count	Colony/g	Max. $1x10^3$
	Coliform Bacteria	APM/g	< 3
	Staphylococcus aureus	Colony/g	Max. 2 x 101
	Clostridium sp.	Colony/g	< 10Max. 5 x 10^1
	Mold/Yeast	Colony/g	
5	Lead (Sn) contamination	mg/kg	Max. 250,0*
6	Arsenic (As) contamination	mg/kg	Max. 1.0

*) packaged in cans

This research offers updates compared to previous research in several aspects. A holistic approach to biomass waste ensures full utilization of dragon fruit peel without complicated extraction processes. The addition of dragon fruit peel directly to jam increases the fibre, anthocyanin, and antioxidant content, offering more comprehensive health benefits and environmental protection. Focusing on compliance with SNI 3746-2008 provides additional assurance for consumers and facilitates product penetration into the market. Comprehensive tests that include multidimensional analysis provide a complete picture of product quality and safety. Apart from that, this research supports the principles of a circular economy, which promotes the sustainability of red dragon fruit farmers while protecting the environment with zero waste. With these various innovations and advantages, this research is expected to produce innovative products that meet SNI 3746-2008 standards and offer significant added value in terms of nutrition and the environment, providing practical solutions that can be implemented by industry to produce healthier and more sustainable products.

2. RESEARCH METHODS

2.1. Materials and Tools

This research used red dragon fruit *(Hylocereus polyrhizus)* from Bantaeng Regency, South Sulawesi, sugar, and pectin to make jam. Meanwhile, pancreatic digest of caseine, yeast extract, glucose, agar, peptone, sodium chloride, disodium hydrogen phosphate, potassium dihydrogen phosphate, and distilled water are required to analyze the jam's quality. All chemicals used were pro-analysis (Merck). This research used various types of equipment, including equipment for making jam, namely blender (Miyako), iron wok, wooden spoons, gas stove, and analytical balance (FUJITSU FS-AR 210 GRAMME). While the equipment used in jam quality analysis includes oven (Thermo Scientific HerathermTM), Laminar Air Flow (JISICO), incubator (THERMO SCIENTIFIC), automatic autoclave (TOMY SX-500), manual autoclave (GEA YX-24LDJ), colony counter (Alishtech J-2), water bath (Memmert WNB 7), desiccator, micropipette, and glassware.

2.2. Methods

This research is a combination of quantitative and qualitative research. Quantitative research was used to analyse the quality of red dragon fruit jam by adding dragon fruit peel in accordance with the jam standards regulated in SNI 3746-2008. Laboratory testing is used to analyse microbial contamination, organoleptics, fibre, and moisture content in the jam. Meanwhile qualitative research was conducted through literature studies to examine and document the application of circular economy principles in the production of red dragon fruit

jam [36]. A descriptive explanation will be presented from literature sources that highlights how the use of dragon fruit peel as biomass waste can be used in making jam and reducing waste disposal [37] [38].

2.2.1 Preparing Jam

The fundamental ingredients for preparing this jam includes 500 g of red dragon fruit flesh, 60 g of dragon fruit peel, 200 g of sugar, and 1 g of pectin. Ripe red dragon fruit without any blemishes on its peel is needed to make jam. The flesh and peel of the red dragon fruit should be separated after peeling. Four times, the same fundamental recipe was created by weighing 240 g of dragon fruit peel and 2000 g of red dragon fruit flesh. Blend the fruit's flesh and peel with 800 g of sugar and 4 g of pectin. Repeatedly blend until all elements are well combined. Smoothly cook the fruit purée over low heat.

2.2.2 Jam Quality Analysis in Line with SNI 3746-2008 Jam Quality Requirements.

2.2.2.1 Microbial Contamination Test: Total Plate Count (TPC)

The Total Plate Count test (TPC) is carried out in accordance with the procedures regulated in SNI 3746-2008 [35], which consist of:

1. Preparing Plate Count Agar (PCA)

   Plate Count Agar preparation procedures to comply with SNI 3746-2008 [35].

2. Preparing Buffer Peptone Water (BPW)

   Buffer Peptone Water preparation procedures to comply with SNI 3746-2008 [35].

3. Sample dilution and casting method

   Sample dilution and casting methods are carried out according to SNI 3748 [35]. The total plate count is calculated according to equation 1:

$$Total\ Plate\ Count\ (\text{Colony/g}) = n\ x\ F \qquad \text{(Eq. 1) [35]}$$

where n as the average of colonies from two petri dishes of a dilution (Colony/g); and F as the average colony dilution factor used.

2.2.2.2 Organoleptic Test

There are two types of methods used in organoleptic tests:

1. Condition Test

   Condition tests include odor, colour and taste tests. Procedures for implementing condition test are carried out in accordance with SNI 3746-2008 [35].

2. Hedonic Test

   The hedonic test was carried out based on SNI 01-2346-2006 with 30 untrained panelists who filled out an assessment sheet consisting of 9 scales indicating the level of liking from really don't like it (scale 1) to very much like it (scale 9) [39]. The data obtained is processed, and the final conclusion is determined according to equation 2:

$$P(\bar{x}\text{-}(1{,}96\frac{s}{\sqrt{n}})) \leq \mu \leq (\bar{x}\text{+}(1{,}96\frac{s}{\sqrt{n}})) \cong 95\% \qquad \text{(Eq. 2) [39]}$$

where n as the number of panelists; 1,96 as the standard deviation coefficient at the 95% level; $\bar{x}$ as the average quality value; and s as the standard deviation of quality values.

2.2.2.3 Fruit Fibre Test

Fruit fibre analysis was carried out according to the procedures in SNI 3746-2008 concerning jam [35].

2.2.2.4 Moisture Content Test

Moisture content analysis is carried out according to the procedures in SNI 01-2891-1992 [40] concerning Methods for Testing Foods and Drinks. Moisture content is calculated according to equation 3:

$$Moisture\ Content\ (\%) = \left[\frac{W_1 - W_2}{W_1 - W_0}\right] \times 100\% \qquad \text{(Eq. 3) [40]}$$

where W_o as the mass of an empty aluminium cup (g); W_1 as the mass of aluminium cup and sample before heating (g); and W_2 as the mass of aluminium cup and sample after heating (g)

3. RESULTS AND DISCUSSIONS

The successful production of red dragon fruit jam with the addition of its peel can be seen in Figure 1.

Figure 1. Red Dragon Fruit Jam Product with Its Peel Addition

3.1 Total Plate Count (TPC) Test

The Total Plate Count (TPC) method measures the total number of living microorganisms in a specific sample [41]. The principle of TPC involves the growth of aerobic mesophyll bacteria, which occurs after incubating the sample in appropriate media for 48 hours at a temperature 35±1 °C [35]. The food and beverage industry often uses TPC to ensure products are free from pathogenic microbial contamination and within safe consumption limits. Packaged fruit jam is susceptible to microbiological contamination because it contains nutrients that support the growth of microorganisms, such as sugar and water. Unhygienic production, packaging, and storage processes increase the risk of contamination by bacteria, mould, or yeast. Furthermore, damaged packaging or loose closures can allow microorganisms from the environment to enter and multiply in the product.

Table 2. Results of Total Plate Count Test in Red Dragon Fruit Jam with Its Peel Addition

Jam Samples	10^{-1} (Colony)	Average TPC Results (Colony/g)	Quality Requirements According to SNI 3746-2008 (Colony/g)	Conclusion	Relative Percent Difference (RPD) (%)
1st repetition	37	$3.6x10^2$	$1x10^3$	Meets SNI requirements	5.56
2nd repetition	35				

According to SNI 3746-2008, the maximum TPC quality requirement for jam products is $1x10^3$ Colony/g [35]. Based on the data in Table 2, the average TPC value was $3.6x10^2$ Colony/g. This shows that the microbial contamination test for TPC criteria on red dragon fruit jam with the addition of its peel has met SNI standards, which means it is safe for consumption. Furthermore, TPC results below the maximum limit demonstrate the implementation of good hygienic standards in the jam production, packaging, and storage processes, thereby minimizing the risk of microbial contamination.

The consistency of results between the first and second repetitions resulted in a Relative Percent Difference (RPD) value of 5.56%. This meets the standards regulated by SNI ISO/IEC 17025:2017, which stipulates that the RPD value is ≤ 10% [42]. This consistency shows that the results obtained are precise, and the test method used is reliable. Precise and reliable testing methods are critical in ensuring that each batch of products produced meets established quality standards, giving consumers the confidence that the product is safe and of good quality.

3.2 Organoleptic Test

Organoleptic testing is a method of testing that uses human senses to assess a product's sensory quality. This test can involve trained or non-trained panelists, depending on the test's specific objectives. Trained panelists are individuals who have received special training, whereas non-trained panelists are those who have received no special training in sensory evaluation. They are typically general consumers who make decisions based on personal preferences and daily consumption experiences.

3.2.1 Condition Test

According to SNI 3746-2008, condition testing of jam products covers three parameters: odor, colour, and taste. This test aims to determine whether the jam product produced is in normal or abnormal condition.

The odor test is based on the principle of organoleptically analyzing the test sample using the sense of smell (nose). The colour test is based on the principle of organoleptically analyzing the test sample using the sense of sight (eyes). Meanwhile, the taste test is based on the principle of organoleptically analyzing the test sample using the sense of taste (tongue) [35].

According to SNI 01-2346-2006, the minimum number of non-standard panelists who must be involved in testing is 30 [39]. The researchers decided to use an odd number of panelists in this test (31 people) in order to avoid the possibility of tie results, which could complicate the interpretation of the data. Using an odd number of panelists ensures that there is always a clear trend in preferences or ratings, whether in terms of colour, odor, or taste. Table 3 contains the results of the conducted condition tests.

According to data from Table 3, the jam condition test results for three parameters, namely color, odor, and taste, show that all three were considered normal by the majority of panelists. Of the 31 panelists involved in the organoleptic test, the color parameter stood out, with 97% of the panelists stating the jam's color was in the normal category. This demonstrates that the jam's visual or color appearance is very consistent and in line with expectations. In contrast, on odor and taste parameters, assessments tend to be more varied. As many as 65% of panelists rated the jam's odor as normal, while 35% felt it was abnormal. The taste parameter showed slightly better results than odor, with 74% of panelists stating that the jam's taste was normal and 26% stating that it was abnormal.

Table 3. Results of Jam Condition Test in Red Dragon Fruit Jam with Its Peel Addition

Sample	Parameters	Condition Test Results		Quality Requirements According to SNI 3746-2008	Conclusion
		Normal	Abnormal		
Jam	Colour	97%	3%	Normal	Meets SNI requirements
	Odor	65%	35%		
	Taste	74%	26%		

The lower ratings of odor and taste compared to colour may be due to a variety of reasons. Variations in raw materials, production processes, and storage can more easily affect odor and taste. For example, differences in the quality of red dragon fruit or sugar used, or variations in ripening and packaging processes, can produce more easily detectable changes in odor and taste compared to colour. There are several steps you can take to improve the consistency and quality of the odor and taste of jam. First, ensure that the raw materials used are fresh and of high quality. Secondly, adhere to strict hygienic standards during the production process to prevent contamination that could compromise the odor and taste. Third, jam formulas and recipes must be measured and applied with great consistency to ensure that each batch of jam has the same odor and taste. By following these steps, the goal is to ensure that the jam not only meets but surpasses consumer expectations in terms of odor and taste, while maintaining its excellent visual appearance.

3.2.2 Hedonic Test

The hedonic test is used to assess the level of consumer liking or preference for a product, which is carried out by panelists. The study involved 30 non-standard panelists who followed the regulations outlined in SNI 01-2346-2006 [39]. The hedonic test carried out includes the level of liking for colour, texture, odor, and taste. The quality factor that draws consumers' attention the most is colour, as it provides an indication of whether they will like the food or not. Apart from colour, texture also plays an important role in consumer evaluation. Texture is a characteristic of a material that results from a combination of several physical properties, such as size, shape, quantity, and the elements that make up the material, that can be perceived by the senses of touch and taste, including the senses of the mouth and sight [43]. Not only colour and texture, but odor also contributes significantly to consumer perceptions of food. Odor is the smell of food products that is produced when volatile compounds from food enter the nasal cavity and are perceived by the olfactory system. These volatile compounds can enter the nose when humans breathe or inhale them, as well as from the back of the throat while a person eats [44]. All these factors together form the taste of food, which is the

biological perception of the sensations produced by materials entering the mouth. The results of the hedonic test on the jam produced can be seen in Figure 2 and Table 4.

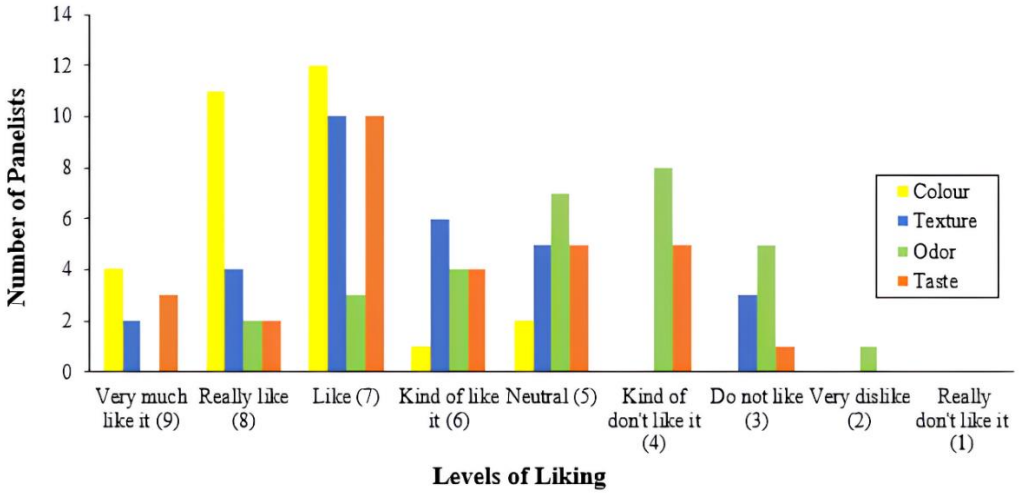

Figure 2. Distribution of Hedonic Test Results Data for Red Dragon Fruit Jam with Its Peel Addition

Table 4. Results of Jam Hedonic Test in Red Dragon Fruit Jam with Its Peel Addition

Parameters	Results of Liking Level	Conclusion of Hedonic Test Value
Colour	$P = 7 \leq \mu \leq 8 \cong 95\%$	7 (Like)
Texture	$P = 4 \leq \mu \leq 5 \cong 95\%$	4 (Kind of don't like it)
Odor	$P = 6 \leq \mu \leq 7 \cong 95\%$	6 (Kind of like it)
Taste	$P = 6 \leq \mu \leq 7 \cong 95\%$	6 (Kind of like it)

Based on the data obtained in Table 4, the colour parameter received a value of 7, which indicates that the panellists liked the colour of the jam. The bright colour of the jam, in line with the characteristics of red dragon fruit, has succeeded in meeting consumer expectations and adding to the visual appeal of the product. However, when turning to odor, this product received a score of 6, which means the panellists only kind of like it the odor of the jam. These values indicate that, although the odor of the jam is acceptable, there is still room for improvement. A scent that is not strong enough, or the presence of an undesirable odor, can reduce the attractiveness of the product. This can be caused by the quality of raw materials, processing methods, or less than optimal storage.

The taste parameter also received a score of 6, indicating that the taste of the jam was only kind of like it by the panelists. The taste of the jam, which the researchers liked somewhat, was probably due to the composition of the ingredients—fruit flesh, fruit peel, sugar, and pectin—not being the right composition for the panelists' tongues. The balance between the sweet, sour, and natural tastes of dragon fruit needs to be considered to increase consumer satisfaction.

The texture parameter received a value of 4, indicating that the panelists kind of don't like it the jam's texture. A texture that does not meet expectations, such as being too liquid or watery, can make the product less attractive. The high moisture content in jam results in a less thick texture, which is not what panelists typically expect from jam products. The optimal texture is thick but still soft, providing a pleasant eating experience. Overall, the average score obtained from the panellists was somewhat favourable, indicating that this product still has the potential to be accepted by consumers.

3.3 Fruit Fibre Test

According to SNI 3746-2008, the quality requirement for jam that meets the standards is that it positively contains fruit fibre [35]. The principle of the fruit fibre test is determining fruit fibre based on visual observation using the eyes. The method used is a qualitative method to determine whether or not there is fibre

in the jam. Figure 3 clearly demonstrates that the addition of red dragon fruit peel to red dragon fruit jam positively contains fine thread-like white fibres.

The pectin in dragon fruit peel, a component of the polysaccharide group, contributes to the presence of fruit fibre in jam [27][52]. The more red dragon fruit peel is added, the higher the pectin content, which is consistent with the increase in fibre. Fruit fibre has an important role in various aspects of health and food quality, such as improving digestive health, controlling blood sugar levels, and improving the texture and stability of products [46].

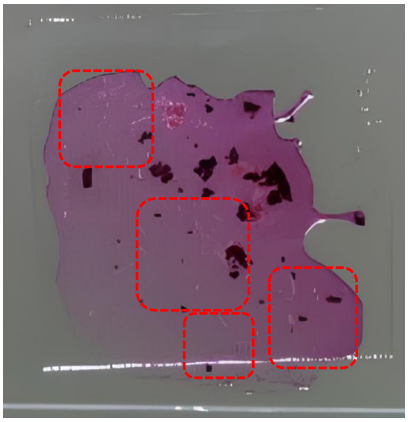

Figure 3. Results of Visual observation of fruit fibre contains fine thread-like white fibres

3.4 Moisture Content Test

Moisture content is the amount of water contained in a product, expressed as a percentage (%) [47]. The main aim of this test is to determine the moisture content contained in red dragon fruit jam using the gravimetric method. The gravimetric method is a quantitative chemical analysis method that involves weighing to determine the amount of substance [48]. The gravimetric method evaporates the water in the jam through heating. The jam sample was heated at 105 °C until it reached a constant weight, indicating that all the water had evaporated [40]. This process requires care to ensure that all water is completely removed without any decomposition of other materials. Knowing the moisture content of products such as red dragon fruit jam is very important because the moisture content can affect the texture, taste, stability, and shelf life of the product. High moisture content can cause the growth of undesirable microorganisms and accelerate product deterioration, while a low water content can affect the sensory quality of the product [48].

Table 5. Moisture Content Results for Red Dragon Fruit Jam with the Addition of Its Peel

Jam Samples	Moisture Content Test Results (%)	Average of Moisture Content (%)	Relative Percent Difference (RPD) (%)
1st repetition	49.4	48.6	3.29
2nd repetition	47.8		

The results of moisture content measurements in Table 5 show that the moisture content in the first and second repetition jam samples were 49.4% and 47.8%, respectively. Huriah et al. [13] reported similar findings, mixing 650 g of red dragon fruit pulp with 350 g of sugar to obtain a jam moisture content of 48.35%. Nurhayati et al. [12] found that the moisture content of red dragon fruit jam was 54.46% when using 1 kg of red dragon fruit flesh without added sugar. This indicates that fresh red dragon fruit flesh has a high moisture content, so that when made into jam, the moisture content remains significant.

Research by Huriah et al. [13] also revealed that by varying the composition of dragon fruit flesh and sugar, it was found that more sugar and less red dragon fruit flesh produced lower moisture content. The research results obtained by using 450 g of red dragon fruit flesh and 550 g of sugar produced a moisture content of 42.61%. To keep the jam healthy with a higher proportion of fruit flesh and less sugar, it is necessary to look for other alternatives. According to Hardita et al. [17], increasing the composition of red dragon fruit peel compared to red dragon fruit flesh can reduce the moisture content in jam. Their research revealed that a

mixture of 10% red dragon fruit flesh and 90% red dragon fruit peel produced jam with a moisture content of 29.46%. On the other hand, a mixture of 90% red dragon fruit flesh and 10% red dragon fruit peel produces jam with a moisture content of 41.05%. This shows that the moisture content in red dragon fruit peel is less than in dragon fruit flesh.

Relative Percent Difference (RPD) is used to assess the precision between two test results. The RPD acceptance standard set by SNI ISO/IEC 17025-2017 is ≤10% [42]. In this study, the RPD value was 3.92%, indicating that the results of two repetitions of the data had high precision.

3.5 Application of Circular Economy in Making Red Dragon Fruit Jam with the Addition of Its Peel

Research on making red dragon fruit jam with the addition of dragon fruit peel is not only intended to improve product quality but also has important implications in the context of a circular economy. The following are the contributions this research has made to the circular economy:

1. Biomass Waste Reduction

Making jam from red dragon fruit peel reduces biomass waste, a byproduct of the fruit processing process. Previously considered waste, red dragon fruit peels now serve as valuable ingredients in food products, thereby reducing waste discharge into the environment and mitigating negative ecosystem impacts, including biomass waste [49]. In a circular economy, biomass plays a major role in the production of material goods and energy. Making a jam from dragon fruit, this it can create sustainable biomass production and its use as a feedstock. Apart from that, the benefits of implementing a circular economy maximally and sustainably in biomass processing are as follows [50][51]:

a. Reducing Waste Pile-up in Landfills: utilising biomass waste for energy and other products can significantly reduce the amount of waste sent to landfills, easing environmental burdens and extending landfill lifespan.
b. Reducing greenhouse gas emissions: the decomposition of biomass waste in landfills produces methane. By processing biomass more efficiently, such as through anaerobic digestion, greenhouse gas emissions can be reduced.
a. Producing Renewable Energy: biomass can be converted into bioenergy, reducing dependence on fossil fuels and lowering the carbon footprint.
b. Creating Value-Added Products: biomass waste can be transformed into valuable products like organic fertilisers, bioplastics, and building materials, reducing waste and creating new economic opportunities.
c. Supporting Sustainable Agriculture: converting agricultural waste into organic fertilisers enhances soil fertility without relying on environmentally harmful chemical fertilisers.
d. Reducing Waste Management Costs: by decreasing the volume and types of waste that need to be managed, waste management costs for governments and industries can be reduced, redirecting resources to more productive uses.

2. Efficient Utilisation of Resources

Research on the use of all parts of red dragon fruit, including the peel, in making jam products supports circular economy principles, which emphasise optimal use of resources. By utilising red dragon fruit peel, which is typically considered waste, the need for additional raw materials can be reduced. Using red dragon fruit peel not only reduces waste but also adds economic value to the final product. In the context of a circular economy, this means that waste is minimized and the use of every piece of raw material available is maximized. This can reduce production costs because additional raw materials are not needed, and waste management costs are also reduced. In addition, reduced production costs can translate into more competitive selling prices in the market, which can increase product competitiveness. Sustainable use of red dragon fruit peel can also open up new market opportunities for those looking for environmentally friendly and sustainable products [52].

3. Increased Product Added Value

The addition of red dragon fruit peel to jam not only increases the nutritional content but also creates added value through product innovation. This can increase product competitiveness in the market and open up

new, wider market opportunities, including for consumer segments that care about health and sustainability [53].

4. Social and economic impacts

Implementation of a circular economy through research innovation in making red dragon fruit jam with the addition of its peel can have a positive social and economic impact on local communities, especially farmers and producers of red dragon fruit. With increasing demand for all parts of the fruit, including the peel, this research can increase farmers' income because they can utilize every part of the red dragon fruit. In addition, by increasing jam processing and production activities, new jobs will be created in the food processing sector, which will provide significant economic benefits for local communities [54].

4. CONCLUSION

This research shows that making red dragon fruit *(Hylocereus polyrhizus)* jam with the addition of its peel provides several significant advantages: (a) Product safety: the jam product's Total Plate Count (TPC) test is $3.6x10^2$ Colony/g, which meets the SNI 3746-2008 standard, making it safe to consume. (b) Fibre content: research results detect the presence of fibre in jam products, which is very beneficial for health. (c) Organoleptic results: condition test results show that the jam is in normal condition for all parameters (odor, colour, and taste). In the hedonic test, the jam product received a score of 6 (kind of like it) for odor and taste and a score of 7 (like) for colour. (d) Implementation of a circular economy: using red dragon fruit peel as an additional ingredient reduces organic waste in the fruit processing industry, increases the economic value of products, and supports sustainable circular economy principles in the food industry. However, there are a few areas that still require improvement: (a) Moisture content: the moisture content in jam remains excessively high, standing at 48.6%. High moisture content can affect the shelf life of the product. (b) Texture: according to the organoleptic test results, the texture of the jam product received a score of 4 (kind of don't like it), indicating the need for improvement.

ACKNOWLEDGEMENT

Thank you to the lecturers who teach the Integrated Chemical Analysis Practice Course, as well as to the Technicians and Laboratory Staff in the Chemical Analysis Study Program, Akademi Komunitas Industri Manufaktur Bantaeng.

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