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The Quality of *Bekasam* Snakehead Fish (*Channa striata*) With the Different Concentration of Saka Sugar (*Saccharum officinarum* Linn) During Different Fermentation Time

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Abstract: Snakehead fish has a high protein content, research has shown that snakehead fish meat contains up to 25.10% protein, 6.22% of which is albumin and can be prepared into *Bekasam*. Generally, the local Kampar community combines fish, roasted rice, and acid in making *Bekasam*. The addition of acid produced a product with a very sour flavor and odor, so another alternative combination is needed. Saka sugar, which is used in the production of traditional foods, contains sucrose, dextrose, and mannose, along with molasses, which can serve as a source of carbohydrates in the fermentation process and can be an alternative in the preparation of bekasm. The objective of this study was to determine the quality characteristics of snakehead fish (*Channa striata*) *Bekasam* with the addition of saka sugar. The method used was an experiment with a Randomized Block Design (RBD). The treatments were the addition of saka sugar at concentrations of 0, 3, 5, and 7%, with fermentation periods of 2, 4, 6, and 8 days. The assessments included organoleptic properties, pH, Aw, total acidity, LAB, and TVB-N. The results indicated that the optimal treatment was 7% sugar (21 g) with a fermentation period of 6 days. The resulting *Bekasam* had the best quality values (color 7.78; flavor 8.00; odor 7.67; and texture 7.59), followed by a pH value of 5.79; Aw value of 0.75; total acidity of 0.96%; LAB of 6.74 Log CFU/g; and TVB-N of 40.49 mg N/100 g.

Introduction

Snakehead fish has an exceptionally high protein content; research evaluating raw extracts and functional values has demonstrated that snakehead fish meat yields up to 25.20 g of protein per 100 g, with 6.22 g of that fraction comprised specifically of albumin (1, 2). In addition, snakehead fish contains ash 4.9 g, fat 0.23 g, and crude fiber 2.50 g (3). The nutrients in snakehead fish, particularly its protein, plays a very important role; for instance, the albumin content in snakehead fish is beneficial in the process of forming new tissues or cells and healing wounds in the body (4). Additionally, snakehead fish has a high moisture content of 80.71% (3). The high protein and moisture content in snakehead fish causes the fish to spoil easily and rapidly (5). Due to this susceptibility to spoilage, processing or preservation is necessary; one method is fermentation, and the resulting product is *Bekasam*.

Bekasam is a product that uses traditional fermentation methods and popular among the public due to its distinctive aroma and taste, as well as its high nutritional value compared to its raw ingredients, which means that LAB will break them into simpler nutrients (6). The quality of *Bekasam* depends on the length of the fermentation period, with the ideal fermentation process lasting 2–8 days, The lenght of the fermentation process affects the total lactic acid bacteria (LAB); the total lactic acid bacteria count increased on the 4th day and decreased on the 8th day, becoming even lower by the 10th day (7). Generally, in the Sumatra region, *Bekasam* is used with freshwater fish, along with salt and a carbohydrate source to provide nutrients for microorganisms during the fermentation process. The carbohydrate sources typically added in *Bekasam* production include rice, glutinous rice cake, flour, cassava, roasted rice, and others (8).

Roasted rice is a source of carbohydrates used by the people of Kampar District, Riau province, Indonesia-in the preparation of *Bekasam*. Roasted rice produces a more desirable *Bekasam* than cooked rice because of its slightly

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \rho_k + \varepsilon_{ijk} \quad \textbf{(Eq. 1)}$$

sour aroma and has the smoky scent from the roasting process, and provides a chewy texture (9). This chewy texture is due to the moisture content in roasted rice being lower at 53.12–57.14% compared to cooked rice at 59.65% (10). The moisture content in roasted rice affects the fermentation process and the chemical composition of the *Bekasam*. The people of Kampar traditionally incorporate kandis acid (Garcinia xanthochymus)—a sun-dried fruit slice native to Southeast Asia known for its intense, sharp acidity—during Bekasam production because it is locally abundant and easily sourced. The addition of acid aims to eliminate the fishy odor, act as a preservative, and aid the fermentation process. *Bekasam* made with added kandis acid results in a very sour taste and aroma (11). Furthermore, the total acidity level was 1.29%. Therefore, an alternative ingredient is needed as an additive in making *Bekasam*. One additive that can be used to optimize the fermentation process of snakehead fish *Bekasam* is saka sugar.

Saka sugar is a type of sugar used by the Kampar community in the preparation of various traditional foods; it is also used as a treatment for thrush and fever. Saka sugar is produced by refining and boiling sugarcane juice using traditional methods, which preserves the natural components of the sugarcane juice and leaves the molasses intact. These components—sucrose, dextrose, and mannose, along with molasses—work in synergy with roasted rice as a carbohydrate source. Furthermore, saka sugar imparts a balanced flavor and aroma to the fermented fish paste. In contrast to its potential as ingredient for fermented products, saka sugar has traditionally been used primarily as a sweetener in desserts and has not been widely utilized as a component in fermentation processes. The research show that the best tasting *Bekasam* made with rice flour as the carbohydrate source was produced by adding 5% palm sugar, with the best organoleptic score of 7, a pH of 4.6, dan a total LAB of 5.7 x 10^6 CFU/g (12). This study aims to analyze the effect of varying saka sugar additions on the quality characteristics (sensory quality & microbial quality) of snakehead fish *Bekasam* during the fermentation process and to determine the optimal concentration for producing snakehead fish *Bekasam* with the best quality characteristics during fermentation.

Methodology

Time and Places

The research was implemented in January–March 2025 at the Fisheries Products Technology Laboratory, the Fisheries Products Microbiology and Biotechnology Laboratory, and the Fisheries Products Chemistry Laboratory of the Faculty of Fisheries and Marine Sciences, University of Riau.

Materials and Equipments

The main ingredient used was 8 kg of snakehead fish species Channa striata, each weight 400 g, purchased at the Panam Market with fish that was freshly cut a few h before the study. The rice used was roasted Anak Daro brand rice. Salt and saka sugar from Payakumbuh, West Sumatra, with specification wrapped in leaves, slender and elongated like a stick. The materials used for microbiological and chemical analysis included MRSA medium (de Mann Ragosa and Sharpe Agar), distilled water, NaCl, H_2BO_3, PCA (perchloric acid), NaOH, phenolphthalein, Tashiro indicator, and HCl.

The equipment used in making *Bekasam* included a 1-L sealed transparent container, a knife, small plastic containers, a basin, a cutting board, an analytical balance, spoons, black plastic, black tape, tissues, and label paper. The microbiological and chemical analysis equipment includes an autoclave, petri dishes, measuring cups, test tubes, aluminum foil, an incubator, a burette, a distiller, a centrifuge, a dropper pipette, a Bunsen burner, a micropipette, a colony counter, a mortar, a hot plate, a pH meter, a moisture meter, and an Erlenmeyer flask.

Experimental Design

The experimental method employed a 4 x 4 factorial arrangement set up in a Randomized Block Design (RBD) with three independent replications, yielding a total of 48 experimental units. The first factor was the concentration of saka sugar at four levels: 0% (S0, control), 3% (S3), 5% (S5), and 7% (S7) (w/w). The s factor was the fermentation duration at four levels: 2, 4, 6, and 8 days. The blocking factor was defined as the batch of raw fish material to account for baseline biological variations across different processing lots. Each experimental unit consisted of a 1-L sealed transparent plastic container packed with approximately 400 g of the prepared fish, salt, and carbohydrate mixture. The data were analyzed using the following statistical model for a two-factor randomized block design (**Equation 1**).

where Y_{ijk} represents the observed response variable (e. g., pH, TVB-N, sensory score) for the i-th saka sugar concentration, j-th fermentation duration, and k-th block is the grand mean; is the fixed effect of the saka sugar concentration (i = 1, 2, 3, 4); is the fixed effect of the fermentation duration (j = 1, 2, 3, 4); is the interaction effect between sugar concentration and fermentation time; is the random effect of the block (k = 1, 2, 3); and is the random experimental error.

Making Roasted Rice

The rice is roasted at a temperature of 100–190 °C for 15 min until it turns brown, gives off a smoky aroma, dries out, and the grains stick together. The roasted rice is left to cool first. Then, the rice is ground until it is powdered.

Making Bekasam

Steak-shaped pieces of snakehead fish meat, which had been washed and drained, were weighed to determine the sample size. The meat was placed in a 1-L clear plastic container, 15% salt was added, and the mixture was left to stand for 30 min. After that, 50% roasted rice was added, followed by saka sugar at concentrations of 0, 3, 5, and 7%. The mixture was stirred evenly and the container was sealed. The mixture was then fermented at room temperature for 2, 4, 6, and 8 days.

Bekasam Characterization

Organoleptic Test

The organoleptic test was conducted by assessing hedonic quality on a scale of 1 to 9 with 1 meaning dislike and 9 meaning like, in accordance with the organoleptic testing guidelines of SNI 01-2346-2006. The hedonic quality assessment involved 25 semi-trained panelists that student of the Fisheries Product Technology Department, Riau University. The methode of hedonic evaluation were observing appearance, flavour, aroma, dan texture. The appearance was carefully observed by displaying the samples in a well area. The flavour and texture were assessed after samples were steam at 100 $^{\circ}$ C for 10 mins before consumption. For aroma samples were placed about 5 cm directly below the nose and the aroma was inhaled deeply 4-5 times.

pH Test

The sample was ground into a fine texture using a mortar, and 10 g of the ground sample was weighed. The weighed sample was homogenized with 10 mL of distilled water. The pH meter was calibrated using pH 4.0 and pH 7.0 buffer solutions prior to measurement. Subsequently, the pH of the homogenized sample was measured, and the value was recorded.

Water Activity (A_w) Test

The sample was placed in the provided container. The sample was then allowed to stand until a reading appeared on the display. Alternatively, the sample was allowed to stand for 15 min until the result was displayed on the meter.

Total Acidity Test

10 g of pickled meat were ground using a mortar and transferred to a 100 mL volumetric flask. Distilled water was added to the mark, and the mixture was allowed to stand for 30 min before being stirred. The resulting solution was filtered, and a 10 mL aliquot of the filtrate was pipetted into a beaker. Two to three drops of phenolphthalein indicator were added, and the solution was titrated with 0.1 N NaOH until a persistent red color was observed. The total acid content was then calculated using the **Equation 2**.

Lactic Acid Bacteria Test

10 g of the sample were homogenized with 90 mL of NaCl solution to obtain a 10^{-1} dilution. A 1 mL aliquot of the homogenate was transferred into a test tube containing 9 mL of NaCl solution to obtain a 10^{-2} dilution. This serial dilution procedure was continued until a 10^{-5} dilution was obtained. From each dilution (10^{-3} to 10^{-5}), 1 mL was transferred into a Petri dish, followed by the addition of 15–20 mL of de Man Rogosa Sharpe agar (MRSA) medium. All dilutions were prepared in duplicate. The contents were mixed thoroughly and incubated at 36–37 °C for 48 h. After colony growth had occurred, plates containing 30–300 colonies were selected, and the bacterial count was determined using the **Equation 3**.

TVB-N Test

10 g of the sample were weighed and homogenized with 90 mL of 6% perchloric acid (PCA) for 10 min. The homogenate was centrifuged at 3, 000 rpm for 15 min, and the resulting supernatant was subjected to distillation. Fifty mL of distilled water were added to the supernatant in the distillation flask, followed by the addition of 10 mL of 20% NaOH until the solution turned red. An Erlenmeyer flask containing 100 mL of 3% boric acid (H_3BO_4) and 3–5 drops of Tashiro indicator was prepared as the receiving flask. Distillation was carried out for 10 min until the receiving solution turned green. A blank was prepared using 50 mL of 6% PCA and was distilled under the same conditions. Finally, both the distillate and the blank were titrated with 0.02 N HCl until a purple endpoint was reached. The titration volume was recorded, and the total volatile base nitrogen (TVB-N) content was calculated using the **Equation 4**.

Data Analysis

The data obtained were tabulated and statistically analyzed using analysis of variance (ANOVA). If the calculated F-value wa greater than the critical F-value at a 95% confidence level, H_1 was accepted; if the calculated F-value was less than the critical F-value, H_0 was accepted. When H_0 was accepted, no significant effect of the treatment was observed, and no further analysis was performed. When H_1 was accepted, a significant effect of the treatment was observed, and a *post-hoc* test was conducted to determine the differences among treatments. The Honest Significant Difference (HSD) test was used as the *post-hoc* test.

Results and Discussion

Organoleptic

Apperance

The highest apperance score was found in the S7-treated snakehead fish fillets, with an average score of 7.39, while the lowest was in the S0-treated fillets, with an average score of 5.75 (see **Table 1**). The S7 treatment met the criteria for brighter visual quality and had a yellowish-brown color. Saka sugar has a yellowish-brown color; this color is produced by the manufacturing process, which involves enzymatic and non-enzymatic browning reactions, namely the Maillard reaction and caramelization (12). The proteins in snakehead fish react with the reducing sugars present in saka sugar. This reaction forms melanoidin brown pigments with high molecular weights.

$$\text{Total Acid Content\%} = \frac{V \times N \times 90 \times 10}{W} \times 100\% \qquad \textbf{(Eq. 2)}$$

$$\text{Colony Count} = \frac{\sum C}{(1 \times n_1) + (0.1 \times n_2) + (0.001 \times n_3) + \cdots + n} \times d \qquad \textbf{(Eq. 3)}$$

$$\text{TVB-N} = \frac{(Vc - Vb) - N \times 14.007 \times 2 \times 100}{W} \qquad \textbf{(Eq. 4)}$$

The reaction begins when the aldehyde or ketone groups in the sugar react with amino acids in the protein, forming glucosamine compounds, ketone or aldehyde groups, and amino groups (13).

During the fermentation process, saka sugar and roasted rice serve as energy sources for LAB growth, leading to the formation of numerous colonies. This causes color degradation; the more energy the LAB use to grow, the more the resulting liquid and color diminish (14). Furthermore, during the fermentation of *Bekasam*, protein and pigment denaturation occurs under low pH conditions, and salt can play a role in the color fading process (15). The breakdown of proteins and lipids during fermentation leads to the formation of low-molecular-weight compounds and high-molecular-weight melanoidins, melanoid is the pigment that makes the color of the snakehead fish darker (16).

The longer the fermentation period and the more energy sources are used, the more LAB will grow, leading to degradation and causing the color to fade. It is worth noting that while lipid oxidation can occasionally influence color degradation and rancidity in fermented fish products, it was not explicitly measured in this study, representing a limitation of the current scope. Nonetheless, given that snakehead fish has an exceptionally low baseline lipid content of 0.23 g per 100 g, the influence of lipid oxidation on appearance and color changes across treatments is likely minor compared to the dominant effects of Maillard browning and microbial metabolism. Future studies should include lipid oxidation indicators to map these secondary interactions over extended storage.

Flavour

The highest flavor quality score was found in the S7-treated snakehead fish *Bekasam,* with an average score of 7.42, while the lowest was the S0 treatment, with an average score of 5.78 (see **Table 2**). The best treatment was S7, which exhibited flavor characteristics of sourness, saltiness, slight savory notes, and slight sweetness. The sour taste is produced by the fermentation process carried out by lactic acid bacteria; these bacteria convert the carbohydrates in roasted rice and the sucrose in saka sugar into organic acids, thereby producing a sour taste. The breakdown of carbohydrates in roasted rice and sucrose in saka sugar results in simple compounds such as lactic acid, propionic acid, and ethyl alcohol. These compounds can cause the sour taste in *Bekasam*, which acts as a preservative (17).

The sweet flavor in snakehead *Bekasam* is produced by the addition of saka sugar. During the fermentation process, saka sugar also undergoes decomposition into organic acids by lactic acid bacteria. However, a sweet flavor from the saka sugar remains in the snakehead *Bekasam*. This residual sweetness from the saka sugar helps balance the sour and salty flavors (12). In addition to sweetness, saka sugar also contributes a sour flavor and produces a caramel-like taste (18).

Aroma

The highest aroma quality score was found in the S7-treated snakehead fish byproducts, with an average score of 7.25, while the lowest was in the S0-treated samples, with an average score of 5.78 (see **Table 3**). The best treatment was S7 with a fermentation duration of 6 days, yielding a score of 7.67 and exhibiting specific quality characteristics: a less acidic, less fresh, typical fermented fish aroma, and a smoky note. The increase in the sour and characteristic aroma scores of the fermented fish paste may be due to the addition of saka sugar. This is because saka sugar, which contains sucrose and glucose, is broken down by lactic acid bacteria during the fermentation

Table 1. Effect of saka sugar concentration and fermentation duration on the appearance score of *Bekasam*.

Saka Sugar Treatment	Appearance Score				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	5.33	5.56	6.22	5.89	5.75 ± 0.39^{a}
3% (S3)	5.56	6.22	6.67	6.33	6.20 ± 0.46^{b}
5% (S5)	6.00	6.96	7.44	7.29	6.92 ± 0.65^{c}
7% (S7)	7.00	7.33	7.78	7.44	7.39 ± 0.32^{d}

Note: Values are presented as mean ± standard deviation. Means followed by different superscript letters (a–d) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

Table 2. Effect of saka sugar concentration and fermentation duration on the flavor score of *Bekasam*.

Saka Sugar Treatment	Flavor Score				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	5.56	5.71	6.00	5.85	5.78 ± 0.19^{a}
3% (S3)	6.00	6.44	7.00	6.78	6.56 ± 0.44^{b}
5% (S5)	6.11	6.59	7.52	7.29	6.88 ± 0.65^{b}
7% (S7)	6.85	7.33	8.00	7.48	7.42 ± 0.47^{c}

Note: Values are presented as mean ± standard deviation. Means followed by different superscript letters (a–c) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

process to produce organic acids (19).

In addition, a caramel aroma is produced in the S7-treated *Bekasam*. The distinctive caramel aroma produced by saka sugar results from a caramelization reaction caused by heat during the cooking of the saka sugar (19). The addition of caramel aroma at the highest concentration of saka sugar causes the smoky aroma to become more intense. Furthermore, the pleasant caramel aroma in the snakehead fish *Bekasam* is derived from the sugarcane used in making the saka sugar, which comes from selected, ripe, and fresh sugarcane. If old sugarcane is used as the raw material of making saka sugar, it will produce a burnt saka sugar aroma (20). The addition of saka sugar helps lower the pH to activate enzymes; furthermore, saka sugar aids in the growth of lactic acid bacteria. Lactic acid bacteria and enzymes play a role in producing the characteristic aroma of *Bekasam*. Furthermore, saka sugar produces a slight caramel aroma in snakehead fish *Bekasam*. Roasted rice also influences the resulting *Bekasam* product; roasted rice produces a smoky aroma and a slight aroma reminiscent of roasted nuts.

Texture

The highest texture quality score was found in the snakehead fish fillets treated with treatment S7, with an average score of 7.22, while the lowest score was for treatment S0, with an average score of 6.58 (see **Table 4**). The best treatment was S7, with an average score of 7.22, which produced snakehead fish fillets that were firm and compact and relatively easy to separate from the bones.

The best treatment was treatment S7, with a fermentation period of 6 days, yielding a score of 7.59; the fish had a chewy and firm texture and was relatively easy to separate from the bone. The saka sugar in the snakehead fish fermented fish had an effect. Saka sugar can increase the acidity of the *Bekasam* snakehead fish. This acidic environment reduces the meat's firmness and adhesion to the bone (12). This chewy texture results from the fact that only a portion of the carbohydrates in the roasted rice is degraded by lactic acid bacteria. Therefore, the water content resulting from the degradation of roasted rice carbohydrates by lactic acid bacteria is not as high as that caused by lactic acid bacteria on rice carbohydrates. The texture produced in tilapia fish paste using rice carbohydrates and the addition of brown sugar becomes less firm and slightly soft (12). Furthermore, the salt in tilapia *Bekasam* also binds the water content present in the fish's body. Additionally, sugar is hygroscopic and can attract water (21). Consequently, the resulting *Bekasam* texture is firmer and chewy.

The longer the fermentation process of snakehead fish by-products, the softer the resulting texture becomes, to the point where it easily falls apart (22). This change in texture is caused by the growth of lactic acid bacteria, which break down the proteins in the snakehead fish meat into amino acids. This process results in a less compact structure and makes the meat more prone to crumbling, as the bonds between the peptide structures have been severed and disrupted by the lactic acid bacteria.

pH

The lowest pH value was found in the snakehead fish *Bekasam* treated with S7, with an average value of 5.94, while the highest was in the S0 treatment, with an average value of 6.44 (see **Table 5**). The best treatment was S7, which had the lowest pH value for the snakehead fish *Bekasam*. The use of saka sugar in the production of snakehead fish fermented paste influences the decrease in pH. The higher the concentration of saka sugar used in the production of snakehead fish fermented paste, the faster the pH will decrease. There is a significant interaction

Table 3. Sensory evaluation of aroma at various saka sugar concentrations and fermentation times.

Saka Sugar Treatment	Aroma Score				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	5.56	5.71	6.00	5.85	5.78 ± 0.19^{a}
3% (S3)	6.00	6.67	7.00	6.78	6.61 ± 0.43^{b}
5% (S5)	6.33	6.78	7.33	7.18	6.91 ± 0.45^{b}
7% (S7)	6.89	7.00	7.67	7.44	7.25 ± 0.37^{c}

Note: Values are presented as mean ± standard deviation. Means followed by different superscript letters (a–c) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

Table 4. Sensory evaluation of texture at various saka sugar concentrations and fermentation times.

Saka Sugar Treatment	Texture Score				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	5.56	5.71	6.00	5.85	5.78 ± 0.19^{a}
3% (S3)	6.00	6.67	7.00	6.78	6.61 ± 0.43^{b}
5% (S5)	6.33	6.78	7.33	7.18	6.91 ± 0.45^{b}
7% (S7)	6.89	7.00	7.67	7.44	7.25 ± 0.37^{c}

Note: Values are presented as mean ± standard deviation. Means followed by different superscript letters (a–c) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

between roasted rice and saka sugar regarding the decrease in pH. This interaction indicates a positive relationship between roasted rice and saka sugar, meaning that the addition of saka sugar during the fish paste production process leads to a decrease in pH (12). This is due to the increased formation of organic acids, particularly lactic acid, resulting from the microbial breakdown of carbohydrates.

The pH value of *Bekasam* depends on the carbohydrate source used. The addition of saka sugar affects the pH value of *Bekasam*. The higher the concentration of saka sugar added, the lower the resulting pH. *Bekasam* with 7% saka sugar produced a pH value of 5.76–5.79. *Bekasam* made with rice as the carbohydrate source produced a lower pH of 4.86 with the addition of brown sugar compared to 5.13 without sugar (12). Saka sugar provides additional energy for lactic acid bacteria to produce acid, thereby creating a low pH environment.

Fermentation period affects the decrease in pH. The results of this study show that *Bekasam* Snakehead fish with treating 7% saka sugar caused a decrease in pH from day 2 to day 8, from 6.53 to 5.76. The research show that *Bekasam* Tilapia experienced a decrease in pH from 6.40 to 5.30 by the day 8 (22).

Water activity (A_w)

The results of the A_w statistics were not affected by the addition of saka sugar or the length of fermentation. The range of A_w values obtained was 0.75–0.80 (see **Table 6**). The A_w values in *Bekasam* snakehead fish with different concentrations of saka sugar tended of decrease. This is related to the osmotic stress response of lactic acid bacteria. The A_w value decreases as the fermentation period lengthens due to the shrinkage of muscle fibers. This affects the availability of free water (23). This decrease in free water availability may be caused by protein denaturation resulting from a drop in pH. The drop in pH causes the protein structure to contract, forcing water out of the meat and thereby reducing the availability of free water. A high A_w value leads to spoilage (24). Sugar can draw water out of food (25). Salt penetrates the food, thereby exerting osmotic pressure on the cells of microorganisms (26).

Table 5. pH value of *Bekasam* at various saka sugar concentrations and fermentation times.

Saka Sugar Treatment	pH Value				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	6.65	6.58	6.48	6.05	6.44 ± 0.27^{c}
3% (S3)	6.45	6.34	6.27	5.98	6.26 ± 0.21^{bc}
5% (S5)	6.43	6.24	6.15	5.88	6.18 ± 0.23^{b}
7% (S7)	6.35	5.87	5.79	5.76	5.94 ± 0.28^{a}

Note: Values are presented as mean ± standard deviation. Means followed by different superscript letters (a–c) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

Table 6. Water activity value of *Bekasam* at various saka sugar concentrations and fermentation times.

Saka Sugar Treatment	Water Activity				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	0.86	0.82	0.78	0.75	0.80 ± 0.05^{c}
3% (S3)	0.84	0.79	0.77	0.73	0.78 ± 0.05^{bc}
5% (S5)	0.82	0.78	0.76	0.69	0.76 ± 0.05^{ab}
7% (S7)	0.80	0.77	0.75	0.68	0.75 ± 0.05^{a}

Note: Values are presented as mean ± standard deviation. Means followed by different superscript letters (a–c) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

Table 7. Total acidity of *Bekasam* at various saka sugar concentrations and fermentation times.

Saka Sugar Treatment	Total Acidity (%)				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	0.40	0.56	0.68	0.76	0.60 ± 0.16^{a}
3% (S3)	0.54	0.66	0.72	0.88	0.70 ± 0.14^{b}
5% (S5)	0.63	0.70	0.78	0.98	0.77 ± 0.15^{b}
7% (S7)	0.81	0.88	0.96	1.11	0.94 ± 0.13^{c}

Note: Values are presented as mean ± standard deviation. Means followed by different superscript letters (a–c) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

Total acidity

The highest total acidity was found in the S7-treated snakehead fish byproducts, with an average value of 0.94, while the lowest was in the S0 treatment, with an average value of 0.60 (see **Table 7**). Saka sugar plays an important role in increasing total acidity.

Saka sugar contains sucrose, which can be hydrolyzed by the enzyme invertase into glucose and then converted into organic acids by lactic acid bacteria (18). The increase in total acidity in the fish sauce with the S7 treatment was due to the fact that saka sugar served as a carbon source for the growth of lactic acid-producing bacteria. Treatment S7 resulted in a total acidity value of 0.94%. Tilapia fish by-products with a 3% sugar addition in treatments with 35% and 40% rice yielded total acidity values of 0.86% and 0.90%, respectively (12). The addition of saka sugar resulted in higher total acidity.

There was an increase in total acidity in the *Bekasam* under the various treatment conditions involving concentration and fermentation duration. This increase in total acidity occurs because the bacteria in the fermented product have entered the logarithmic growth phase; additionally, the number of bacteria synthesizing carbohydrates into acids increases, leading to higher total acidity (14). However, excessive addition of saka sugar will result in lower total acidity in the tilapia *Bekasam*.

On the production of joruk (fermented fish) with the addition of 25% palm sugar showed the lowest acidity level of 0.38%, compared to 0.71% for the 20% palm sugar addition (27). If bacteria are left in a concentrated sugar solution, water from the cells will exit through the membrane and flow into the sugar solution because sugar is hygroscopic. As a result, the microorganisms undergo plasmolysis, thereby inhibiting their growth.

Research shows that lengthening the fermentation duration results in an increase in total acid content, accompanied by a decrease in pH (28). The longer the fermentation, the more lactic acid bacteria are produced, resulting in a higher total acid content (29).

Lactid Acid Bacteria (LAB)

The highest total lactic acid bacteria count was found in the S7-treated snakehead fish offal, with an average value of 6.37 Log CFU/g, while the lowest was in the S0 treatment, with an average value of 6.22 Log CFU/g (see **Table 8**). Treatment S0 resulted in a lower total lactic acid bacteria count, ranging from 5.83 to 6.61 Log CFU/g. This is attributed to the physical properties of the roasted rice, which is very hard and difficult to break down during the fermentation process, thereby limiting bacterial growth (30). Therefore, treatment with the addition of saka sugar was applied to enhance lactic acid bacteria growth.

There was an increase in the treatment group that received saka sugar compared to the group without saka sugar. Treatment S7 produced the highest total lactic acid bacteria count, ranging from 5.96 – 6.77 CFU/g. Saka sugar contains sucrose, which can serve as a growth medium for lactic acid bacteria. Lactic acid bacteria can thrive when sufficient nutrients are available and the environment is optimal. Increased glucose concentration during fermentation leads to higher levels of lactic acid bacteria and halophilic bacteria (31). Carbohydrate and sugar sources can be utilized by lactic acid bacteria as an energy source (32). This energy source is broken down by microbial enzymes to produce lactic acid, which lowers the pH. A low pH can inhibit the growth of other microorganisms and bind total acid during the fermentation process (33). This is due to an increase in the number of lactic acid bacteria that break down sugar into lactic acid (7).

The amount of lactic acid bacteria on the eighth day of fermentation showed a slight increase and tended to remain stable. This was because the lactic acid bacteria had entered the stationary phase. The stationary phase occurs when the number of bacteria that die is equal to the number of bacteria that grow (35). Similar to the previous study, the addition of ground chili resulted in a LAB count of 6.5 log CFU/g on the third day, which then decreased to 5.5 log CFU/g on the fifth day (35).

TVB-N

The lowest TVB-N value was found in snakehead fish offal treated with S7, with an average value of 39.51, while the highest was in the S0 treatment, with an average value of 49.12 (see **Table 9**). The TVB-N values in *Bekasam* snake head fish with added saka sugar at different concentrations were still lower compared to the *Bekasam* without added saka sugar. The TVB-N values of milkfish (Chanos chanos) offal without any additives ranged from 237.07 to 395.70 mg N/100 mL (36). Meanwhile, the results of the study on snakehead fish *Bekasam* with added saka sugar showed TVB-N values of 31.84–54.00 mg N/100 mL. Furthermore, the TVB-N values of snakehead fish by-products with the addition of 7% saka sugar, ranging from 31.84 to 48. 35 mg N/100 mL, which is not significantly different from the results of a recent study), in which tilapia fish offal with the addition of

Table 8. Effect of saka sugar concentration and fermentation duration on the lactic acid bacteria population (Log CFU/g) of *Bekasam*.

Saka Sugar Treatment	Lactid Acid Bacteria (Log CFU/g)				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	5.83	5.87	6.57	6.61	6.22 ± 0.43^{a}
3% (S3)	5.86	5.91	6.63	6.65	6.26 ± 0.43^{b}
5% (S5)	5.91	5.95	6.71	6.73	6.32 ± 0.46^{c}
7% (S7)	5.96	6.00	6.74	6.77	6.37 ± 0.45^{d}

Note: Means followed by different superscript letters (a–d) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

turmeric had TVB-N values of 32.06–41.66 mg N/100 mL (37).

Furthermore, the TVB-N values of snakehead fish waste treated with 7% sugar, ranging from 31.84 to 48.35 mg N/100 mL, were not significantly different from the *Bekasam* tilapia with the addition of turmeric had TVB-N values of 32.06–41.66 mg N/100 mL (37). This indicates that saka sugar plays a role in inhibiting decomposition.

The TVB-N values in this study were lower than those in other TVB-N reference values. This was due to the addition of saka sugar, which accelerated the fermentation process. Consequently, few volatile bases were formed. The decomposition of trimethylamine and nitrogenous bases was reduced due to the low pH value.

Lactic acid bacteria break down nitrogen compounds such as urea and amino acids into volatile basic components. Volatile components resulting from the microbial degradation of amino acids include ammonia, monoamines, diamines, putrescine, and cadaverine (12). These compounds cause the foul odor in fish that have deteriorated in quality due to the activity of microbes and enzymes that break down protein compounds. therefore, the duration of fermentation affects the TVBN value because the number of lactic acid bacteria that degrade proteins increases as the fermentation process continues, resulting in a higher TVBN content.

Conclusion

Varying saka sugar concentrations (0%, 3%, 5%, and 7%) and fermentation times significantly influenced the quality characteristics of snakehead fish Bekasam. Based on the statistical and optimization analysis, the combination of 7% saka sugar and a 6-day fermentation period was determined to be optimal. This treatment significantly maximized sensory scores (appearance: 7.78, taste: 8.00, aroma: 7.67, texture: 7.59), establishing a balanced, firm, and consumer-preferred profile. Chemically and microbiologically, this optimal point achieved a stable low pH of 5.79, an Aw of 0.75, a total acidity of 0.96%, and a robust lactic acid bacteria count of 6.74 Log CFU/g, while successfully minimizing the total volatile basic nitrogen (TVB-N) to a safe level of 40.49 mg N/100 g. Extending fermentation to 8 days offered no statistical advantages; rather, it caused structural softening and an unfavorable rise in volatile nitrogen compounds.

Abbreviations

SNI: Indonesian National Standard; RBD: Randomized Block Design; LAB: Lactic Acid Bacteria; TVB-N: Total Volatile Base Nitrogen; Aw: Water Activity; PCA: Perchloric Acid; MRSA: de Man, Rogosa, and Sharpe Agar; HSD: Honest Significant Difference;

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Not applicable.

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Table 9. Total Volatile Basic Nitrogen (TVB-N) content (mg N/100 g) at various saka sugar concentrations and fermentation times.

Saka Sugar Treatment	TVB-N				Average
	Day 2	Day 4	Day 6	Day 8	
0% (S0)	40.64	46.63	50.16	59.04	49.12 ± 7.69^{d}
3% (S3)	35.91	42.19	46.36	54.00	44.62 ± 7.59^{c}
5% (S5)	33.33	40.25	43.11	51.59	42.07 ± 7.56^{b}
7% (S7)	31.84	37.35	40.49	48.35	39.51 ± 6.89^{a}

Note: Values are presented as mean ± standard deviation. Means followed by different superscript letters (a–d) within the same column indicate statistically significant differences based on Honest Significant Difference (HSD) at $p < 0.05$.

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