



The effect of using different bamboo on the characteristics of sui wu'u fermented meat from Bajawa, Nusa Tenggara Timur

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ABSTRACT

This research aimed to analyze the characteristics of beef sui wu'u prepared by storing the meat product in different types of bamboo. The research design used four treatments with five storage replications: P1: green betung bamboo (*Dendrocalamus asper*), P2: brown betung bamboo (*Dendrocalamus asper*), P3: talang bamboo (*Schizotachyum brachcladum*), P4: gombong bamboo (*Gigantocloa verticillata*). The research showed that the different types of bamboo storage had a significant effect ($P<0.05$) on the physical characteristics of beef sui wu'u in terms of yield, final pH, water holding capacity and hardness. Among the chemical characteristics, using different types of bamboo had a significant effect ($P<0.05$) on the water and protein content of beef sui wu'u. The organoleptic characteristics showed the different types of bamboo storage container had a significant effect ($P<0.05$) on colour, aroma, texture and overall acceptability, but for the colour dimensions, L*, a*, b*, Cab, hab, Y, X, Z, x, y, Wi, Ti, and Tw, there were no significant effects ($P>0.05$). The microbiological characteristics of the sui wu'u for all types of bamboo used were within the standard limits fermented meat products. The use of different types of bamboo influences the characteristics of beef sui wu'u in terms of physical, chemical, colour dimensions, organoleptic characteristics and microbiology. The use of containers made from brown betung bamboo (*Dendrocalamus asper*) produces better beef sui wu'u than the other bamboo types. Nonetheless, the use of talang bamboo and gombong bamboo can also be recommended in the process of making sui wu'u, but the final beef product had different characteristics from the sui wu'u stored in brown betung bamboo, and was especially different from sui wu'u stored in talang bamboo.

1. Introduction

Traditional meat fermentation utilizes the activity of bacteria or enzymes that occur during the fermentation process, where bacterial or enzyme activity is obtained from the raw materials used in the meat fermentation process or from the type of container used during the process of fermentation. The fermented meat product traditional found in East Nusa Tenggara, Indonesia, is sui wu'u. The name sui wu'u, according to the local Flores

people, is derived from sui (meat) and wu'u (corn flour). Although sui is the general word for all types of meat, it can specifically refer to beef. A similar, related product is called hui wu'u when based on pork (hui in the local language). Therefore, the product's name depends on the meat used, but regardless, this product is fermented meat coated with salt and corn flour and then stored in bamboo containers, locally called tuku. According to (Rubak, Lalel, & Sanam, 2023), sui wu'u is a product produced by the people of Bajawa, East Nusa Tenggara, using

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preservation by traditional methods, i.e., by coating the meat with salt then storing it in bamboo (tuku) for six months. *Febrianti et al.* (2021) the type of bamboo used is betung (aka petung) bamboo (*Dendrocalamus asper*), which contains bioactive compounds, such as phenolics, flavonoids, lignans, tannins. Research conducted by (*Chee et al.*, 2020) showed that *D. asper* contains phenolics and flavonoids (total phenolic content measured via Folin-Ciocalteu), has antioxidant activity measurable using the DPPH method, as well as enzymatic activity, such as inhibiting α -amylase and α -glucosidase. In addition, *Lactococcus lactis* was isolated from sui wu'u (*Rubak, Lalel, Sanam, et al.*, 2023).

The characteristics of fermented meat products are their specific taste, texture and long shelf-life, all a result of both natural fermentation or from added cultured microorganisms (*Zhong et al.*, 2021). Various fermented meat products are traditionally produced across Asia, the principles of which are almost the same as sui wu'u (*Wang et al.*, 2022; *Zhong et al.*, 2021; 2022), including a local product from Hunan and Guizhou, China, with added rice flour and salt. Apart from that, the same principle applies to Cang-kuk fermented meat product and this processed product comes from Kuantan Singingi, Riau, Indonesia, and has added betung bamboo shoots, rice and salt (*Mirdhayati*, 2022). Furthermore *Endo et al.* (2014), a type of fermented processed product, Jinhua ham, is a fermented traditional product from Jinhua, China, a pork product coated with salt and stored for two months. Nham is a fermented pork product from Thailand, where the meat contains added rice, garlic, 2% salt (w/v), pepper, chilli, nitrate and is fermented for 3–4 days. Sai-krok-prieo and Mum are fermented sausages originating from Thailand that contain sugar, pepper, chilli, salt and are fermented for 2–3 days. Nem Chua is a processed fermented meat product from Vietnam where lean meat and skin are mixed with additives and chilies and fermented for 3–4 days. Urutan, a fermented sausages product from Bali, Indonesia contains lean meat mixed with chili, sugar, and salt. *Olatunde et al.* (2023), various fermented meat products are popular, namely Arjia from India, Yak Kargyong from Himalayan regions, Chartaysha, Kargyong, and Suka Ko Masu from India, Nem Chua from Vietnam, Sai-Krok-Prieo from Thailand and Tocin from the Philippines. According to *Bamidele et al.* (2023), many fermented meat products originate from Africa, namely Soudjouk/Sucuk, Boubnita, Pastirma, Afo-nnama, Beirta, Miriss, Dodery, Gueddid, and Khilii/Khlia.

Relatively few studies have been conducted on the characteristics of sui wu'u. *Naju et al.* (2022) showed that the use of different corn flours does not influence the organoleptic characteristics of the sui wu'u produced, and 0.5 kg of flour is optimal to preserve 250 g of landrace pork stored for one month using betung bamboo. *Febrianti et al.* (2021) found that using 0.5 kg of corn flour in 250 g of meat and 6% (w/w) salt, with storage for 1 month, did not affect the pH value, water holding capacity, cooking loss, or total lactic acid bacteria. Research into the physicochemical, microbiological and organoleptic characteristics after six months of storage by (*Rubak, Lalel, & Sanam*, 2023), using the ratio of meat (60%): corn flour (30%): salt (5%), showed the sui wu'u contained essential nutrients for the human body and was safe for consumption. According to *Di Gioia* (2015), the quality and manufacturing consistency of fermented processed products is greatly influenced by many factors, namely the raw materials used, which must be fresh and have low contamination, the consistent presence of fermentative microorganisms, application of strict sanitation, and proper control of time, temperature and humidity during fermentation. Furthermore *Bamidele et al.* (2023) stated that some fermented meat products can be classified as shelf-stable meat. Several variables that contribute to the stability of microbial populations in fermented meat products are low pH, high growth rate of lactic acid bacteria, low water activity, long drying time, and the added salt and seasonings. The previous research results were the basis for initial data on the formula used to make sui wu'u in the current study. This study aimed to analyze the characteristics of beef sui wu'u stored in different types of bamboo (tuku) in terms of physical, chemical, colour, organoleptic, and microbiological characteristics.

2. Materials and Methods

2.1 Sui wu'u preparation

Traditional sui wu'u preparation was previously described in detail (*Febrianti et al.*, 2021; *Naju et al.*, 2022).^{Briefly}, 250 g of beef was cut into dimensions of 5 cm × 6 cm × 0.5 cm. Dry corn crumble (500 g, i.e., 200% of the weight of beef) were coarsely ground into corn crumble. The cut beef was coated with 6% (w/w) salt, left to rest for 5 minutes, then completely coated with corn crumble (w/w). Corn crumble was layered into the bamboo (tuku). The first, followed by a layer of coated meat; thereafter, alternate layers of corn crumble and coated

beef were added, with corn crumble as the final layer. After that, covered with bamboo and stored for 30 days at room temperature (27–29 °C).

2.2 Research Design

The study was a completely randomized design with four treatments, each with five replications. Treatments were the four different types of bamboo, P1: brown betung bamboo (*Dendrocalamus asper*), P2: green betung bamboo (*Dendrocalamus asper*), P3: talang bamboo (*Schizotachyum brachcladum*), P4: gombong bamboo (*Gigantocloa verticallata*).

2.3 Physical Characteristics

Water holding capacity (WHC) was measured using the Hamm method (Soeparno, 1994); 0.3 g of sui wu'u was placed on Whatman 42 filter paper and then pressed using two glass plates (modified press equipment) with a weight of 35 kg for 5 minutes. The area of the flattened meat was drawn on the filter paper and then entered into the formula (equations 1, 2, 3). Cooking loss (CL) (Kong et al., 2023; Lu et al., 2022; Zhang et al., 2023) was measured by weighing 5 g of sui wu'u into a polythene plastic bag and heating in a water bath at 80 °C. Then, the cooked meat was cooled to 25 °C and held for 15 minutes before being dried and weighed and entered into the formula (equation 4) to yield the cooking loss. The pH was measured using a previously published method (Hiemori-Kondo et al., 2022). Sui wu'u was homogenized with twice its weight of distilled water, and the pH of the homogenized solution was measured using a pH meter (Ezdo PH5011, China). Hardness was measured (Zhang et al., 2023) using a texture analyzer (Brookfield CT3

4500, USA). Colours *L, *a, *b were measured using a colour meter (Color Meter TES 135A, Republic of China, Taiwan) with standards *L (brightness), *a (redness), and *b (yellowness).

$$\text{milimigrans H}_2\text{O} = \frac{\text{we area (cm}^2\text{)} - 8.0}{0.0948} = x \quad \text{Eq 1}$$

$$\text{wet area level} = \frac{X}{\text{sample weight (g)}} = x100\% \quad \text{Eq 2}$$

$$\text{wet holding capacity} = \frac{\% \text{ water content} - \% \text{ wet area level}}{\text{}} \quad \text{Eq 3}$$

$$\text{Cooking Loss (\%)} = \frac{W - W_o}{W} = x100\% \quad \text{Eq 4}$$

Information, w = weight of meat,
Wo = wight of meat after cookint

2.4 Chemical Characteristics

Contents of water, protein, fat, and carbohydrates in the sui wu'u were measured according to commonly used methods (AOAC, 2005).

2.5 Organoleptic Characteristics

Organoleptic quality of the sui wu'u was measured using 25 semi-trained panellists. Organoleptic testing used a hedonic quality test on a scale of 1–5 to look at colour, aroma, taste, texture and level of liking. The hedonic quality scale is shown in Table 1.

2.6 Microbiological Characteristics

Total plate count (TPC) and counts of *Escherichia coli*, and *Staphylococcus aureus* were conducted by standard methods (National Standardization Agency of Indonesia, 2008).

Table 1. Sui wu'u organoleptic quality hedonic scale

Parameter	Hedonic quality score				
	1	2	3	4	5
Colour	Pale red	Red	Slightly reddish brown	Quite brownish red	Brownish red
Aroma	Aroma off	Does not have the typical sui w'u aroma	Has a slight typical sui wu'u aroma	Has a quite typical sui wu'u aroma	Has a typical sui wu'u aroma
Taste	Tasty off	Not sour	Slightly sour	Quite sour	Sour
Texture	Not solid	Slightly not solid	Slightly solid	Quite solid	Solid
Acceptance	Do not like	Slightly do not like	Slightly like	Quite like	Like

2.7 Data analysis

Data on physical characteristics, i.e., yield, pH of meat, final pH, percentage of lactic acid, water holding capacity, cooking loss, colour characteristics of sui wu'u (L^* , a^* , b^* , Cab, hab values, Y, X, Z, x, y, Wi, Yi, Tw), as well as chemical characteristics (water, protein, fat and carbohydrate) were analyzed by one-way ANOVA, and if an effect was measured, Duncan's test was used. Organoleptic characteristics (colour, aroma, taste, texture and level of acceptance) were analyzed using Kruskal-Wallis, and if they were influential, with Mann-Whitney analysis. Microbiological characteristics (TPC, *E coli*, and *S. aureus* counts) were analyzed descriptively. Data were tabulated using Microsoft Excel and analysed using SPSS version 29 software. Data were presented as mean SD ($P < 0.05$).

3. Results and Discussion

3.1 Physical Characteristics

The measured physical characteristics of beef sui wu'u were yield, pH of fresh beef, final pH of the sui wu'u product, percentage of lactic acid, water holding capacity, cooking loss, and hardness. Different types of bamboo (tuku) influenced the physical characteristics of the beef sui wu'u produced after being stored for 30 days. The physical characteristics of beef sui wu'u produced using the different types of bamboo are shown in Table 2.

The sui wu'u yield value was in the range of 49.34 ± 9.19 (talang bamboo) to $65.49 \pm 5.04\%$ (green betung bamboo). The initial pH of the beef used was in the range 5.58 ± 0.086 to 5.61 ± 0.145 , which was

within the normal range. After storage for 30 days, the final pH of beef sui wu'u was in the range of 5.32 ± 0.346 (green betung bamboo) to 6.95 ± 0.934 (talang bamboo). The percentage of lactic acid in the sui wu'u was in the range $0.378 \pm 0.293\%$ (talang bamboo) to $0.678 \pm 0.146\%$ (green betung bamboo). The water holding capacity of sui wu'u was in the range $18.01 \pm 2.08\%$ (talang bamboo) to $28.79 \pm 1.79\%$ (brown betung bamboo). The cooking loss was in the range $23.31 \pm 5.98\%$ to $25.94 \pm 7.48\%$. The hardness was in the range of 119.30 ± 39.06 g (green betung bamboo) to 368.40 ± 262.77 g (talang bamboo) (Table 2). The statistical analysis showed that the physical characteristics of sui wu'u were influenced by the type of bamboo used. Namely, using different types of bamboo had significant effects ($P < 0.05$) on yield, pH, water holding capacity, and hardness, but no significant effects ($P > 0.05$) on lactic acid content or cooking loss.

Green betung bamboo produced a higher yield of sui wu'u compared to the use of other types of bamboo. This is likely because green betung bamboo has the characteristic texture of young bamboo and has a high-water content. The use of talang bamboo produced the lowest yield compared to the use of other types of bamboo. This is perhaps because talang bamboo is thinner than the other bamboos, so the better air circulation caused the sui wu'u in talang bamboo to be drier than that in the other bamboo types. Also, the water content reduces during storage, which logically is affected by the thin talang bamboo allowing more water reduction than the other bamboos used. The yield of sui wu'u produced was significantly affected ($P < 0.05$) by the characteristics of the bamboo used, as bamboo contains water, cellulose,

Table 2. Physical characteristics of beef sui wu'u prepared using different types of bamboo

Parameter	P1	P2	P3	P4	P-Value
Yield (%)	55.97 ± 3.79^a	65.50 ± 5.04^b	49.34 ± 9.19^a	56.67 ± 4.29^a	0.005
pH fresh beef	5.58 ± 0.086	5.61 ± 0.179	5.58 ± 0.126	5.61 ± 0.145	0.964
pH sui wu'u	5.46 ± 0.377^a	5.32 ± 0.346^a	6.95 ± 0.934^b	5.67 ± 0.467^a	0.002
Lactic acid percentage(%)	0.414 ± 0.117	0.678 ± 0.146	0.378 ± 0.293	0.564 ± 0.081	0.060
Water Holding Capacity (%)	28.79 ± 1.79^b	27.73 ± 2.25^b	18.01 ± 2.08^a	27.98 ± 0.678^b	0.000
Cooking Loss (%)	25.05 ± 6.10	25.94 ± 7.48	25.25 ± 5.92	23.31 ± 5.98	0.927
Hardness (g)	147.60 ± 28.82^a	119.30 ± 39.06^a	368.40 ± 262.77^b	229.80 ± 70.52^{ab}	0.049

P1: brown betung bamboo (*Dendrocalamus asper*), P2: green betung bamboo (*Dendrocalamus asper*) P3: talang bamboo (*Schizoztachyum brachcladum*), P4: gombong bamboo (*Gigantocloa verticallata*).

^{a,b} Different superscript letters in a row indicate values are significantly different ($P < 0.05$)

lignin and hemicellulose. Previous research (Han et al., 2023) reported that the characteristics of structural bamboo segments, including their hierarchy, the vascular pattern bundle distribution, and fibre morphology have significant differences from multi-pore vascular bundles and irregular fibre morphology in the case of moso bamboo. Besides that, every type of bamboo has a specific structure, pore, porosity, chemical components and contents. According to Subekti et al. (2015), the chemical composition of bamboo is different for each species, so in betung bamboo, the chemical composition is 51.20% cellulose, 24.51% lignin and 0.32% nitrogen. Zhang et al. (2018); Zhang et al. (2019), bamboo is hygroscopic, which allows the processes of absorption and desorption of water from the environment when the relative humidity changes, thus effecting changes in bamboo's water content; the cellulose, hemicellulose, and lignin play roles in this.

The pH range of the meat used to produce sui wu'u was normal (Puolanne et al., 2001), as the normal post-rigor pH of beef ranges from 5.60 to 6.48. According to Wyrwisz et al. (2019), the pH of beef *longissimus lumborum* is pH 5.51 to 5.68. During 30 days of storage, the pH of the meat decreased, except for sui wu'u in talang bamboo and gombong bamboo—the pH of these products increased. This shows that the characteristics of the bamboo used influences the final pH of the sui wu'u produced. Differences could also be due to the high activity of lactic acid bacteria during the storage process in brown and green betung bamboo, causing the lower final pH of sui wu'u from these suku. According to Zhong et al. (2021), during the fermentation stage, the pH decrease from the initial pH of fresh beef to the final pH of sui wu'u provides the advantage of inhibiting the growth of several harmful bacteria and ensuring the quality of fermented meat. Furthermore Chelule et al. (2010), the decreasing pH from fermentation to below about pH 5 could be detrimental to the fermenting microorganisms, so usually the pH of fermented product remains at a pH somewhat below 5. According to Sun et al. (2016), the decrease in pH was greater in sausages inoculated with lactic acid bacteria. According to Puolanne et al. (2001), effect the combination of salt and pH is important for regulation of salt use and meat pH to reach a high enough level of water holding capacity. However, the pH of sui wu'u produced using containers made from talang bamboo and gombong bamboo had a higher pH compared to the initial pH of the fresh meat. According to Feiner (2006), pH

influences colour, shelf life, taste, microbiological stability, yield and texture of meat and meat products. The pH value of meat and meat product (raw fermented Salami) is around 4.6 and 6.4. Meat of pH >6.4 becomes damaged due to enzyme activity that produces large amounts of by-products from metabolism, unpleasant odours, and discolouration.

The lactic acid content was inversely correlated with the final pH of sui wu'u, where the higher the final pH, the lower the lactic acid content, and vice versa. According to Wang et al. (2022), fermentation reduces the pH drastically and the lactic acid content is negatively correlated, so the lactic acid content increases in line with decreasing pH. Sui wu'u is stored in talang bamboo had a lower percentage of lactic acid compared to other types of product. This is influenced by the lactic acid bacteria conversion of glycogen into lactic acid, as was indicated by the carbohydrate content of sui wu'u fermented in talang bamboo being numerically higher than in sui wu'u from other bamboo containers (Table 4). The low percentage of lactic acid could be influenced by the physical characteristics of talang bamboo, i.e., it is a thin bamboo, so outside air can likely more easily enter the internal bamboo spaces, thus giving the sui wu'u its characteristics.

The characteristics of the bamboo used influenced the sui wu'u water holding capacity, sui wu'u stored in talang bamboo had lower water holding capacity than product from the other types of bamboo. An increase in meat pH will increase the impression of juiciness and the water holding capacity and will decrease the cooking loss in sheep muscles linearly (Soeparno, 1994). Apple & Yancey (2013) reported positive and negative charges of muscle myofibril are in equal proportions at its isoelectric point, so the charged parts are attracted to each other, thereby reducing the amount of water that can be attracted to the myofibril. If the pH is below the isoelectric point, it causes an excess of positive charge, but if the pH is above the isoelectric point, there is an excess of negative charge, resulting in a greater attraction to water. According to Puolanne et al. (2001), salt is also involved in the ability to hold water, so water holding capacity is affected by the pH of the raw material. However, if meat is combined with NaCl, this combination is expected to keep the high pH so the water holding capacity remains high. However, this was in contrast to our results, where the high pH (pH=6.948) in sui wu'u stored in talang bamboo had a lower water holding capacity that other products with lower pH but higher water holding capacity. Other research Puolanne & Peltonen (2013) studied the combination of pH and salt content in dry sausages

during fermentation and drying, where at the beginning of fermentation, the ability to bind water was close to optimal. Then, simultaneously with a decrease in pH and an increase in ionic content, water holding capacity can end up above the optimal point so that it is possible to bind the particles cohesively, and this can have an impact on the resulting texture. The gel formed by the coagulation of dissolved proteins will stabilize the structural cohesiveness and low water-holding capacity during the fermentation process.

The use of different bamboos did not affect the cooking loss. Cooking loss is influenced by pH and water-holding capacity. According to *Torley et al.* (2000) cooking loss is influenced by a significant interaction between cooking temperature, and ionic strength, pH, and triphosphosphate. The high hardness value of sui wu'u was influenced by the characteristics of the bamboo used. Sui wu'u stored in talang bamboo had different characteristics compared to product from betung bamboo. Furthermore, the hardness of sui wu'u was also closely related to the water content. The sui wu'u produced using talang bamboo containers was drier compared to sui wu'u from other types of bamboo. Similar effects were also obtained by (*Wang et al.*, 2023), in that shear force was related to hardness and was influenced by the loss of water content as a result of the length of drying. Accordingly *Hu et al.* (2022);

Van Wezemaal et al. (2014), there is a relationship between water content and the level of hardness. Furthermore *Hu et al.* (2021) reported that hardness is influenced by water content and water activity. Apart from that, the level of hardness is influenced by the decrease in water content and pH of dry fermented sausages (*Bozkurt & Bayram*, 2006).

3.2 Colour Dimension Characteristics

The use of different bamboo types did not influence the colour characteristics of beef sui wu'u (Table 3). Treatment P3 (sui wu'u produced in Talang bamboo), with respect to L*, tended to be darker and with respect to a* tended to be redder than the other bamboo types, but differences were statistically insignificant ($P>0.05$). Physically, the results show that beef sui wu'u had a pale red colour unless using a talang bamboo container.

Colour characteristics of beef sui wu'u can be measured using the CIELAB method (*Warris*, 2000), this method develops through changing colours into imaginary primaries X, Y, and Z. The values X, Y, and Z are tristimulus that describe colours as points in space. The tristimulus value is used to calculate three coordinates L*, a*, and b*. L* is the component or value of lightness, while a* indicates red-greenish colour and b* indicates yellow-bluish colour. The

Table 3. Colour characteristics of beef sui wu'u prepared using different types of bamboo

Parameter	P1	P2	P3	P4	p-Value
L*	24.02±12.73	24.06±9.74	21.342±5.729	24.003±19.066	0.982
a*	19.59±16.18	29.76±43.47	33.755±28.945	24.512±42.805	0.923
b*	-37.56±30.36	-31.631±37.022	-36.786±35.995	-39.326±42.161	0.989
Cab*	62.80±41.25	53.388±49.488	59.710±30.280	66.454±37.665	0.962
hab	269.06±73.58	244.646±123.248	247.150±115.150	242.212±99.041	0.975
Y	7.22±9.15	4.834±2.499	3.635±1.397	8.841±14.244	0.774
x	0.254±0.107	0.304±0.090	0.283±0.108	0.251±0.130	0.847
y	0.186±0.092	0.224±0.121	0.190±0.134	0.190±0.159	0.963
X	8.13±8.33	6.716±1.601	5.769±1.196	10.172±12.154	0.803
Z	14.58±8.10	12.726±8.703	12.920±8.534	18.841±16.002	0.794
Wi	372.40±224.36	265.444±261.140	339.440±301.112	408.026±277.570	0.855
Yi	-272.064±224.18	61.122±197.306	-220.796±233.416	-188.060±190.574	0.102
Tw	-20.043±69.62	-46.418±63.925	-16.786±80.381	-14.446±79.160	0.893

P1: brown betung bamboo (*Dendrocalamus asper*), P2: green betung bamboo (*Dendrocalamus asper*) P3: talang bamboo (*Schizotachyum brachcladum*), P4: gombong bamboo (*Gigantocloa verticallata*).

L*, a*, b* values influence Wi, Yi, and Tw assessments. The low L* in sui wu'u was likely influenced by a browning reaction which is characterized by the formation of a dark colour. According to *Bozkurt & Bayram* (2006) the dark colour in fermented meat is formed as a result of the formation of nitrosomyoglobin, which plays a role the desired darker colour formation and is influenced by a decrease in water content. This indicates that fermented meat products will be a darker colour than the meat used to produce them. The positive a* value indicated similar red colours of the different sui wu'u products, although talang bamboo tended to produce a redder sui wu'u colour than the others (Figure 1). This was likely a result of salt reactions during fermentation. According to *Chelule et al.* (2010), stable haemoglobin S-nitroso, which is marked by a bright red colour, forms as a result of the reaction of nitrite with myoglobin during roasting, fermentation or cooking processes. Furthermore, according to (*Hu et al.*, 2021, 2022), the red colour is formed as a result of the formation of nitrosomyoglobin occurring due to the decrease in pH. The b* values measured reflected that some blueness was noticeable in our sui wu'u. This is different from other research (*Hu et al.*, 2022), where fermented sausage reflects a yellow colour. This is caused by a decrease in pH. The formation of yellow pigment is a reaction between lipid oxidation products and amines in the phospholipid group or amines in proteins.

3.3 Chemical Characteristics

The chemical characteristics of beef sui wu'u using different bamboo types are shown in Table 3. The statistical analysis showed that the use of different types of bamboo produced significant effects ($P<0.05$) on the water and protein content of the sui wu'u. However, bamboo type did not significantly affect ($P>0.05$) the carbohydrate or fat content of the sui wu'u. During fermentation, the chemical content is indicated to be changed by lactic acid bacteria, which can be naturally found in the bamboo used. Research conducted by (*Rubak, Lalel, Sanam, et al.*, 2023), discovered the lactic acid bacteria, *Lactococcus lactis* isolated from sui wu'u.

The water content of beef sui wu'u was in the range $41.47\pm8.14\%$ (talang bamboo) to $58.81\pm2.90\%$ (green betung bamboo). The protein content of beef sui wu'u was in the range of $26.99\pm2.50\%$ to $37.72\pm1.50\%$, seen in product from green betung bamboo and talang bamboo, respectively. The carbohydrate content of beef sui wu'u was in the range of $6.56 \pm 1.57\%$ to $11.65 \pm 7.04\%$, seen in product from gombong bamboo, and talang bamboo, respectively. The fat content of the sui wu'u was in the range of $1.13\pm 0.31\%$ (brown betung bamboo) to $1.99 \pm 0.812\%$ (green betung bamboo) (Table 4).

The characteristics of the bamboo used as a container in making sui wu'u influences the chemical content of the product, where the use of talang bamboo

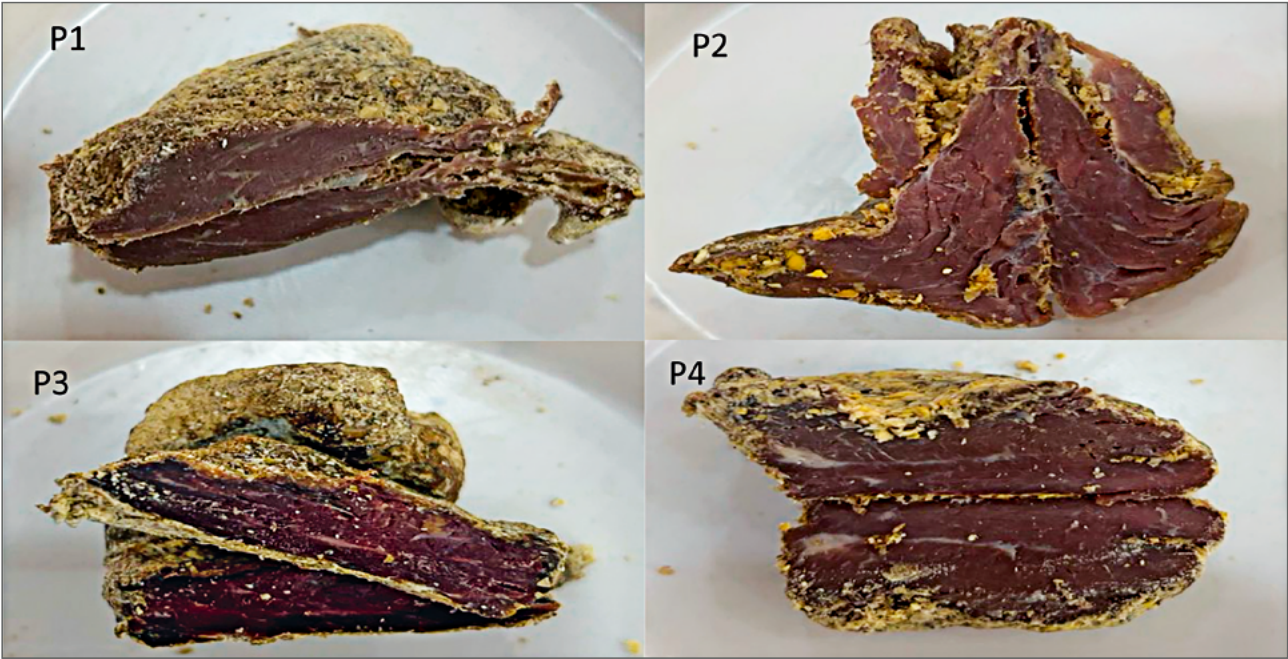


Figure 1. Beef sui wu'u prepared using different types of bamboo. P1: brown betung bamboo (*Dendrocalamus asper*), P2: green betung bamboo (*Dendrocalamus asper*) P3: talang bamboo (*Schizoztachyum brachcladum*), P4: gombong bamboo (*Gigantocloa verticallata*).

Table 4. Chemical characteristics of beef sui wu'u prepared using different types of bamboo

Parameter	P1	P2	P3	P4	P-Value
Water (%)	54.04±4.09 ^b	58.81±2.90 ^b	41.47±8.14 ^a	54.54±2.49 ^b	<0.001
Protein (%)	30.70±3.82 ^b	26.99±2.50 ^a	37.72±1.50 ^c	32.66±1.95 ^b	<0.001
Carbohydrate (%)	9.63±1.86	8.65±1.86	11.65±7.04	6.56±1.57	0.247
Fat (%)	1.13±0.314	1.99±0.81	1.84±0.594	1.57±0.498	0.143

P1: brown betung bamboo (*Dendrocalamus asper*), P2: green betung bamboo (*Dendrocalamus asper*) P3: talang bamboo (*Schizotachyum brachcladum*), P4: gombong bamboo (*Gigantocloa verticallata*).

^{a,b,c} Different superscript letters in a row indicate values are significantly different ($P < 0.05$)

results in lower water content and greater protein content. According to Subekti *et al.* (2015), each type of bamboo has different chemical components. Furthermore, according to (Han *et al.*, 2023), bamboo species have different morphologies and structures. The water and protein content of the sui wu'u produced in the current study was higher, but the fat content was lower compared to research by (Rubak, Lalel, & Sanam, 2023), where the water, protein and fat content of pork sui wu'u stored in betung bamboo for 6 months was 6.11±0.09, 24.29±0.21 and 59.68±0.07, respectively. This difference is influenced by the type of meat used and storage time. The decrease in water content is also influenced by the activity of microorganisms. According to Zhong *et al.* (2021), during fermentation there will be a decrease in water content, which can be beneficial for inhibiting pathogen microorganisms. The use of water by microorganisms and the addition of salt, the precipitation of water was facilitated, resulting in a decrease in water content during fermentation.

3.4 Organoleptic Characteristics

The change in chemical components in beef due to fermentation will affect the organoleptic characteristics of beef sui wu'u. The scores for the organoleptic characteristics of beef sui wu'u using different types

of bamboo are shown in Table 5. The statistical analysis showed that the use of different types of bamboo had significant effects ($P < 0.05$) on the colour, aroma, texture and overall acceptance of beef sui wu'u, but showed an insignificant effect ($P > 0.05$) on the taste of beef sui wu'u.

Sui wu'u colour scores ranged from 3.51±1.64 to 4.01±1.32, while aroma scores ranged from 2.50±1.26 to 3.31±1.30. The sui wu'u texture scores ranges from 2.57±1.34–4.03±1.11. The taste scores of sui wu'u ranged from 3.64±1.07 to 3.81±1.06, and overall acceptance scores of sui wu'u were from 3.23±0.899 to 3.60±0.916 (Table 5).

Sui wu'u stored in talang bamboo tended to have a lower aroma score compared to the products from the other bamboos, indicating the aroma produced differs in the talang bamboo product. The difference in the aroma of sui wu'u using talang bamboo (compared with the aroma of the other products) could have been caused by the higher pH as a result of the activity of by-products produced during fermentation. According to Feiner (2006), if the pH is around 6.4, meat can be damaged due to enzyme activity, producing large amounts of by-products from metabolism, unpleasant odours and discolouration. The beef sui wu'u produced in all the bamboo containers had quite a sour taste. This indicates that during storage in bamboo,

Table 5. Organoleptic characteristics of beef sui wu'u prepared using different types of bamboo

Parameter	–	P2	P3	P4	P-Value
Colour	3.51±1.64 ^a	3.64±1.30	3.63±1.42 ^a	4.01±1.32 ^b	0.035
Aroma	2.59±1.38 ^{ab}	3.31±1.30 ^c	2.50±1.26 ^a	2.86±1.44 ^b	0.000
Taste	3.81±1.06	3.71±1.01	3.64±1.07	3.65±1.02	0.487
Texture	2.57±1.36 ^a	3.06±1.44 ^b	4.03±1.11 ^c	3.99±1.18 ^c	0.000
Acceptance	3.60±0.916 ^b	3.35±0.927 ^a	3.23±0.899 ^a	3.38±0.905 ^{ab}	0.036

P1: brown betung bamboo (*Dendrocalamus asper*), P2: green betung bamboo (*Dendrocalamus asper*) P3: talang bamboo (*Schizotachyum brachcladum*), P4: gombong bamboo (*Gigantocloa verticallata*).

^{a,b,c} Different superscript letters in a row indicate values are significantly different ($P < 0.05$)

the expected fermentation processes occurred, characterised by a sour taste. The sui wu'u texture scoring showed that products made from talang and gombong bamboo containers were different from those produced using betung bamboo. This is closely related to the water content of sui wu'u, as the sui wu'u content of beef using containers made of talang bamboo had a lower water content compared to other types of bamboo (Table 4), and besides that, could also be influenced by the characteristics of the bamboo type. The overall acceptance assessed by the panellists showed they had a specific level of acceptance for each bamboo container used, and each sui wu'u produced from different types of bamboo had its own characteristics that were liked by the panellists. The degradation of protein and fat components by natural microorganisms found in bamboo and beef during the fermentation process, likely influences the characteristics of the aroma and taste of fermented sui wu'u. According to Zhong et al. (2021), microorganisms degrade both protein and fat during long fermentation processes to produce small molecules of peptides, amino acids fatty acids, etc., and the appropriate degradation process helps form a fermented meat taste.

The use of different types of bamboo influences the characteristics of beef sui wu'u in terms of colour, aroma, texture, and level of acceptance. The use of containers made from brown betung bamboo provided better organoleptic characteristics of beef sui wu'u compared with the other bamboo types studied.

3.5 Microbiological Characteristics

The microbiological characteristics of the beef sui wu'u produced using different types of bamboo are shown in Table 6. These results indicate that the sui wu'u produced was within the standard limits for *E. coli* and *S. aureus* contamination. The TPC of beef sui wu'u produced was in the range of

1.10x10⁹ CFU/g to 2.80x10⁹ CFU/g. Sui wu'u from gombong bamboo showed a higher TPC compared to the other treatments. Based on SNI 7388:2009 standards (National Standardization Agency of Indonesia, 2009), the TPC of processed whole or cut meat product should be below 1x10⁵ CFU/g. The higher TPC in our sui wu'u was likely not caused by the presence of pathogenic bacteria, but could be due to the presence of lactic acid bacteria which played a role in the fermentation process. The TPCs from our current research were higher than in research conducted by (Rubak, Lalel, & Sanam, 2023), i.e., the TPC of pork sui wu'u stored in betung bamboo for approx. 6 months was 4.4 × 10⁵ CFU/g. (Rubak, Lalel, Sanam, et al., 2023) isolated *Lactococcus lactis* from sui wu'u, and reported that the total lactic acid bacteria count in pork sui wu'u is around 3.7 × 10³ CFU/g.

According to (BPOM: Food and Drug Supervisory Agency) (Food and Drug Supervisory Agency, 2019), the maximum number of *E. coli* in meat and fermented processed meat products without heat treatment is around 10³ CFU/g. *E. coli* was not detected in the beef sui wu'u in our study, regardless of the type of bamboo used. *S. aureus* contamination in the sui wu'u was 1.00x10³ CFU/g for all types of bamboo used, which did not exceed the permitted level in SNI 7388:2009 standard (National Standardization Agency of Indonesia, 2009). According to (BPOM: Food and Drug Supervisory Agency) (Food and Drug Supervisory Agency, 2019), a maximum of 10⁴ CFU/g of *S. aureus* is permitted in meat, processed meat products and fermented meat without heat treatment.

Most fermented products can experience contamination by spoilage bacteria, expressed during storage. Several types of pathogenic bacteria are commonly found in fresh meat, such as *Campylobacter*, *E. coli* serotype O157:H7, and *Salmonella*, while *L. monocytogenes* and antibiotic-resistant bacteria, such as *Campylobacter* and *Salmonella* (Dixon

Table 6. Microbiological characteristics of beef sui wu'u prepared using different types of bamboo

Parameter	BPOM				
	PP BPOM No. 13/2019 Fermented processed meat product	P1	P2	P3	P4
TPC (CFU/g)	-	1.20×10 ⁹	1.50×10 ⁹	1.10×10 ⁹	2.80×10 ⁹
<i>Escherichia coli</i> (CFU/g)	10 ³ CFU/g	-	-	-	-
<i>Staphylococcus aureus</i> (CFU/g)	10 ⁴ CFU/g	1.00×10 ³	1.00×10 ³	1.00×10 ³	1.00×10 ³

P1: brown betung bamboo (*Dendrocalamus asper*), P2: green betung bamboo (*Dendrocalamus asper*) P3: talang bamboo (*Schizotachyum brachcladum*), P4: gombong bamboo (*Gigantocloa verticallata*). - : not found

et al., 2023) can also occur. According to *Ramos et al.* (2023), *S. aureus* and its toxins cannot be avoided with certainty in alkaline foods because its spores can survive. However, according to *Dong et al.* (2024): a decrease in pH not only affects organoleptic properties but can play a role in suppressing pathogens and spoilage microorganisms during fermentation and the final safety of the product. The sui wu'u produced, in terms of microbiological characteristics, was not influenced by the type of bamboo used, as can be seen from the microbiological profile.

Overall, beef sui wu'u produced in all four types of bamboo had acceptable levels of *E. coli* and *S. aureus* that were within the maximum permitted levels. Therefore, beef sui wu'u produced using the different bamboo types and stored for 30 days would be safe to consume with regard to these pathogens.

4. Conclusion

The use of different types of bamboo container influences the characteristics of beef sui wu'u in terms of physical, chemical, colour, organoleptic and microbiological aspects. The use of containers made from brown betung bamboo (*Dendrocalamus asper*) produces better beef sui wu'u. However, the individual use of talang and gombong bamboos can also be appropriate in the process of making sui wu'u, although compared with the sui wu'u stored in brown betung bamboo, the final products will have different characteristics in terms of physical, chemical and organoleptic aspects. Microbiological characteristics met the standards and showed the products were safe for consumption with respect to *S. aureus* and *E. coli* levels.

Uticaj korišćenja različitih vrsta bambusa na karakteristike fermentisanog mesa sui wu'u iz Bajave, Istočna Nusa Tenggara

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INFORMACIJE O RADU

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APSTRAKT

Ovo istraživanje imalo je za cilj analizu karakteristika govedeg sui wu'u, pripremljenog čuvanjem proizvoda od mesa u različitim vrstama bambusa. Eksperimentalni dizajn obuhvatio je četiri tretmana sa po pet ponavljanja skladištenja: P1 – zeleni betung bambus (*Dendrocalamus asper*), P2 – smeđi betung bambus (*Dendrocalamus asper*), P3 – talang bambus (*Schizostachyum brachycladum*) i P4 – gombong bambus (*Gigantochloa verticillata*). Rezultati istraživanja pokazali su da je vrsta bambusa imala značajan uticaj ($P < 0,05$) na fizičke karakteristike sui wu'u, uključujući randman, konačnu pH vrednost, sposobnost vezivanja vode i tvrdoću mesa. Kada je reč o hemijskim osobinama, korišćenje različitih bambusa značajno je uticalo ($P < 0,05$) na sadržaj vode i proteina. Organoleptičke analize pokazale su da je vrsta bambusove ambalaže značajno uticala ($P < 0,05$) na boju, aromu, teksturu i ukupnu prihvatljivost proizvoda. Međutim, kada su u pitanju dimenzije boje (L^* , a^* , b^* , C_{ab} , h_{ab} , Y , X , Z , x , y , W_i , T_i i T_w), nije uočen statistički značajan uticaj ($P > 0,05$). Mikrobiološke karakteristike sui wu'u kod svih korišćenih vrsta bambusa bile su u granicama standarda za fermentisane proizvode od mesa. Upotreba različitih vrsta bambusa utiče na fizičke, hemijske, organoleptičke i mikrobiološke karakteristike sui wu'u, dok razlike u dimenzijama boje nisu bile značajne. Najbolji kvalitet sui wu'u postignut je korišćenjem smeđeg betung bambusa (*Dendrocalamus asper*), ali se i talang i gombong bambus mogu preporučiti u procesu proizvodnje, iako gotov proizvod pokazuje različite karakteristike, naročito u poređenju sa sui wu'u skladištenim u talang bambusu.

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