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RESEARCH ARTICLE

Effects on Finisher Crossbred Pigs Carcasses Fed Diets Supplemented with Different Levels of Skipjack Tuna Waste

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ABSTRACT

This research assessed the characteristics of pig carcasses fed with skipjack tuna waste (STW) as a partial substitute for concentrate in their diet. A total of 20 castrated male pigs aged 20 weeks and weighing around 60-61 kg were used, originating from a cross between the Landrace and Yorkshire. The feed ingredients comprise corn, fine bran, concentrate, and STW flour. A Completely Randomized Block (CRB) was employed, featuring four treatments and five replications. Each replication included four finisher phase pigs with the treatments as follows: R0 = 0 % STW flour + 20 % concentrate, R1 = 4 % STW flour + 16 % concentrate, R2 = 8 % STW flour + 12% concentrate, and R3 = 12 % STW flour + 8 % concentrate. Data analysis was conducted using ANOVA. The results obtained show that there are differences ($p<0.05$) in the variables of slaughter weight (SW), carcass weight (CW), and loin eye area (LEA). Conversely, the variables of ration intake (RI), carcass length (CL), carcass percentage (CP), and backfat thickness (BFT) did not show different effects ($p>0.05$). STW can be considered a partial substitute for concentrate in pig rations and benefits pig carcasses.

INTRODUCTION

Pigs are genetically recognized for their rapid growth rate, attributed to their capacity to convert food into meat with a high carcass percentage (Carcò et al., 2018). The carcass is the central part of meat-producing livestock, which consists of the body parts of pigs after deducting the head, feet, internal organs, and skin. The quality of pig carcasses is influenced by the composition of the feed, which contains protein and energy (Silalahi & Chen, 2023). Protein is one of the nutritional components essential for the life of livestock, including the growth and development of tissues and the replacement of damaged livestock body cells (Nunes et al., 2020). Optimal growth can yield quality carcasses and can be attained by supplying feed with nutritional content tailored to their life stage (Cemin et al., 2019).

For most small and medium-sized pig farms in Indonesia, the provision is problematic; the high costs of raw materials, namely concentrate, are still dependent on imports and pose the main obstacle to its provision. Indeed, the challenges related to health, environment, and community acceptance remain major setbacks in pig farming development (Patr et al., 2014).

Skipjack tuna (*Katsuwonus pelamis*), is among the most abundant and widely sought species worldwide. It is a pelagic, tropical marine fish distributed in warm seas worldwide, predominantly in the Pacific, Atlantic, and Indian Oceans. North Sulawesi Province is one of Indonesia's skipjack tuna production centers, with an average of 180.000 tons annually for 2015-2022 (BPS-Indonesa Statistics Agency, 2023). Abundant nutritional high-quality content is found in this fish, with 20-25 grams of proteins per 100 grams with all essential amino acids and omega-3 fatty acids (EPA and DHA) at 0.5-1 gram per 100 grams. It is also a rich source of essential vitamins and minerals, particularly selenium, at 30-50 micrograms per 100 grams, along with phosphorus, potassium, and iron (Mahaliyana et al., 2015). However, the production is also followed by an increase in the volume of waste produced, which can reach around 200-300 kg of heads, bones, skin, and offal waste (Jayathilakan et al., 2012). Improperly managed fish waste disposal can also cause environmental problems such as pollution, foul odor, and decreased quality of aquatic ecosystems (Malaweera et al., 2014). Recycling this waste reduces greenhouse gas emissions usually produced from the processing and disposal of fishery waste (Sondakh et al., 2024). Thus, this skipjack tuna waste (STW) is worth considering as a substitute for some of the concentrates in pig rations and an effort to reduce waste generated from its processing.

Previous research has examined pig carcass quality and traits, and they are affected by the partial substitution of concentrates with a range of substances. Iberian pig production, sweet white lupin provides a sustainable and advantageous substitute for soybean meal, enhancing the meat's quality and environmental effect (Garc et al., 2024). The provision of moringa leaf solution increased feed efficiency and improved carcass quality (Suryani et al., 2021). Adding distilled rice grain supplements of up to 10% in feed improved growth performance and reduced feed costs per kg of body weight in growing pigs (Kyawt et al., 2019). Carcass and meat quality were influenced by production systems, environment, genetics, diet and health, age, sex, and reproductive management (Sánchez-Macías et al., 2018). Applying coffee skin flour as a substitute for feed in the ration at a level of 25% also increased CL (Timbulus et al., 2017). Using palm sugar up to 2% increased the amount of water consumption by 7.78 liters/day and waist circumference by 43.72 cm, but not backfat thickness (BFT) (Ango et al., 2016), Feeding the mother without antibiotics interfered with growth performance during the breeding period but did not affect overall growth performance (Skinner et al., 2014). Substituting peanut chips in pigs causes reduced meat weight (Newman et al., 2011). However, the use of tuna skipjack waste as a partial substitute for concentrate in pig rations has not been reported. On the other hand, the availability of tuna skipjack waste as remnants of fish canning industry production is very abundant. These waste piles will pollute the environment if not utilized optimally. This problem indicates the urgency for more cost-effective and sustainable locally-produced alternative feed ingredients.

Therefore, the research aims to bridge the knowledge gap by evaluating the characteristics of pig carcasses fed with STW as a partial substitute for concentrate in the ration.

MATERIALS AND METHODS

Ethical Approval

The animal experiment procedures used in this research complied with the Animal Experiment Protocol of the Commission for Animal Ethics University of Sam Ratulangi, Manado, Indonesia, No. 06/KEH-UNSRAT/REC/2023 and were validated through Animal Ethics Clearance.

Experimental Design and Location

This research used a Randomized Complete Block with four treatments and five replications. The pigs were assigned to blocks according to their initial live weight and randomly within those blocks based on treatment.

The experiment was conducted at Degloty Pig Farm, Lansot Village, Tomohon City, North Sulawesi Province, at about 1,000 m above sea level. Daytime temperatures are 22.5 °C and 19.5 °C at night. Significant rainfall occurs during the year, even in the driest month, averaging 337 mm^3 and an average air humidity of 87% (BPS-Indonesia Statistics Agency 2023).

Feed Ingredients Used

The feed ingredients for the ration consisted of yellow corn, fine bran, concentrate, and STW flour. The proportion of feed types mixed in the ration based on each treatment (R0, R1, R2, and R3) is shown in (Table 1), while the content of minerals, vitamins, and nutrients in ration per treatment is presented in (Table 2).

Table 1. Composition of Experiment Feed Ingredients

Feed Ingredients (%)	Treatments			
	R0	R1	R2	R3
Corn	60	60	60	60
Bran	22	22	22	22
Concentrate	18	14	10	6
Skipjack tuna waste meal	0	4	8	12
Total	100	100	100	100

Table 2. Composition of feed elements of experimental rations

Treat-ments	Elements					
	PK (%)	Fat (%)	SK (%)	Ca (%)	P (%)	EM (Kkal/kg)
R0	14,63	7,60	4,33	0,75	0,67	3169
R1	15,23	7,35	4,16	1,05	0,82	3212
R2	15,38	7,65	3,88	1,35	0,98	3255
R3	15,69	7,81	3,71	1,65	1.14	3298

Experimental Procedure

The experiment was conducted from July 2023 to August 2023 or for 60 full days. The initial adjustment period is seven days (preliminary), followed by a data collection phase of 53 days. This research used individual cages measuring 150 x 90 x 100 cm, equipped with a 50 x 50 cm concrete feeder and a drinking place, and cleaned twice daily.

All pigs used in the experiment were healthy, and no signs of illness were observed. A total of 20 castrated male pigs aged 20 weeks and weighing around 60-61 kg were used, originating from a cross between the Landrace and Yorkshire. Each pig was placed randomly in each cage individually.

Each replication (experimental unit) used four pigs with the following treatments: R0 = 0% STW flour + 20% concentrate; R1 = 4% STW flour + 16% concentrate; R2 = 8% STW flour + 12% concentrate and R3 = 12% STW flour + 8% concentrate.

Feeding and drinking were provided *ad libitum* for 60 days. Pigs were slaughtered after being fasted for 24 hours and then weighed. The number of pigs slaughtered was 20 according to age, and slaughtering was carried out following the SOP issued by the Directorate of Veterinary Public Health, Directorate General of Animal Husbandry and Animal Health, Indonesia Ministry of Agriculture (DKMV, 2022). Furthermore, the carcass produced was weighed, and CW, LP, BT, and LEA measurements were taken.

Experimental Variables

1) Ration Intake (RI) (head/day) was obtained by weighing the amount of ration given minus the remaining ration. The remainder of the ration is weighed in the morning using a seated scale.

2) Slaughter Weight (SW) (kg) was obtained by weighing pigs just before slaughter.

3) Carcass Weight (CW) (kg) was obtained after the body was separated from the contents of the abdominal cavity, fur, and head and then weighed.

4) Carcass Length (CL) (cm) was measured by drawing a straight line from the front edge of the first rib to the front edge of the thigh bone (pelvis).

5) Carcass Percentage (CP) (%) was calculated from carcass weight (kg) divided by slaughter weight (kg) multiplied by 100%.

6) Loin Eye Area (LEA) (cm^2) was measured by drawing the cross-sectional area of the longissimus dorsi muscle between the 10th and 11th ribs, then calculated using a block millimeter.

7) Back Fat Thickness (BFT) (cm) was measured after pigs were slaughtered using a ruler in three places above the first rib, last rib, and thigh joint. The measurement results from the three places were summed and then averaged.

Statistical analysis

The data obtained were analyzed by ANOVA using the General Linear Model procedure of Minitab 2016 ver. 16.2. Pair-wise comparisons with a confidence level of 0.95 were used to determine the effect of STW. The Dunnet's Test (Least Significant Difference/LSD) will be used as a post-hoc test when STW shows a significant effect ($p<0.05$) on the observed variables. The results are presented as the pooled standard error of the mean (SEM).

RESULTS AND DISCUSSION

The results showed that the provision of STW in the ration had a significant effect ($p<0.05$) on the variables SW ($p=0.04$), CW ($p=0.04$), LEA ($p=0.03$), and BFT ($p=0.02$). Meanwhile, the variables RI, CL, and CP showed no significant differences ($p>0.05$). The lower SEM value shows that the mean of treatment reflects actual data more accurately. The impacts of pigs fed a diet supplemented with STW flour during the experiment are presented in Table 3. The mean value indicates the most efficient and effective treatment for each variable in achieving optimal carcass quality, specifically R3, with a substitution of 12% STW flour and 8% concentrate (Table 3).

Table 3. Effects of finisher pigs fed a diet supplemented with skipjack tuna waste flour

Variables	R0	R1	R2	R3	Mean	SEM	*p*-Value
RI (head/day)	2,85	3,00	3,08	3,16	3,02	0,07	0,085
SW (kg)	111,80^{a}	116,10^{b}	117,40^{b}	121,40^{ab}	116,68	1,963	0,025
CW (kg)	79,92^{a}	81,00^{b}	85,98^{b}	89,40^{b}	84,08	1,531	0,003
CP (%)	71,51	69,95	73,24	73,66	72,09	1,601	0,367
CL (cm)	89,60	92,80	93,00	94,00	92,35	1,782	0,361
LEA (cm^2)	42,32^{a}	44,55^{b}	48,49^{ab}	45,37^{b}	45,18	0,982	0,026
BFT (cm)	3,58^{a}	3,36^{b}	3,34^{b}	3,28^{b}	3,39	0,076	0,060

Note: R0 = 0% STW flour + 20% concentrate, R1 = 4% STW flour + 16% concentrate, R2 = 8% STW flour + 12% concentrate, R3 = 12% STW flour + 8% concentrate, SEM= Standard error mean. ^{a,b} Different superscripts at the same row indicate significant differences (P<0.05).

Ration Intake (RI)

The ANOVA showed that the partial substitution of concentrate with skipjack tuna waste flour at levels 4%, 8%, and 12% had the same impact ($p>0.05$) on the pig's RI. The possible cause is that the treatments R1, R2, and R3 are still within the recommended standards, resulting in the same increase in body length. This is in line with previous research stating that the content of nutrients, including protein and energy, and the balance of calcium and phosphate minerals in the treatment ration given to pigs in relatively the same amount provide similar responses (Chassé et al., 2021). The nutritional content of almost similar feed ingredients also influences the body (Kong et al., 2021). The development of the body is, in turn, affected by the nutritional level of the ration used (D'Occhio et al., 2019). STW had several dietary benefits. For example, protein and amino acid content can improve the nutritional profile of feed, while omega-3 fatty acids improve health and growth and reduce dependence on traditional protein sources and imported concentrate, potentially minimizing feed costs (Mahaliyana et al., 2015).

Results indicate that some of the concentrates in pig rations can be replaced with STW flour without disruption. STW flour has a relatively good nutritional profile and can be quite well utilized by pigs.

Slaughter Weight (SW)

The average results obtained using STW flour with 0 %, 4 %, 8 %, and 12 % as a partial substitute for concentrate in the ration ranged from 111.8-121.4 kg with a general average of 116,68 kg. This result differed from the previous study, which stated the range of marketed body weight was 90-110 kg with a general average of 94.02 kg (Lapian et al., 2013). The ANOVA showed that providing STW with levels of R0 (0 %), R1 (4 %), and R2 (8 %) in the ration had a significantly different effect ($p<0.05$) on SW. The Dunnet's Test showed that the treatment without STW (control/R0) produced a lower SW than the other treatment using STW 8% (R2) and 12% (R3). The R3 treatment showed the most optimal SW yield.

The higher the substitute level of STW, the greater the SW. The consistent increase from R0 to R3 shows that the treatment positively affects the pig's SW. This may show increased growth performance or feed efficiency, presumably because STW flour contains high nutritional value, specifically protein content rich in essential amino acids, including lysine and methionine (Mahaliyana et al., 2015). Studies also support this by stating that the need for nutrients, specifically protein for pigs, is related to energy availability (Kong et al., 2021). Meat formation during the growth period of pigs requires protein and energy intake following specific needs (Fung et al., 2019). The primary tissues in the body that experience growth are the skeleton, muscle, and fat (Kyawt et al., 2019). Weight gain is greatly influenced by management and the physiological environment, specifically feed. Therefore, when the feed consumed by livestock does not fulfill needs in terms of nutrient content, optimal growth cannot be achieved (Curry et al., 2019).

Impacts on Carcass Weight (CW)

CW is an essential indicator of the overall meat yield of pigs. Based on the data in Table 3, the mean CW ranged from 79.92 to 89.94 kg or a general mean of 84.08 kg in various treatments (R0 to R3). This weight is higher than the previous study, which had an average weight of 67,22 kg of pigs born to superovulated mothers before mating journal (Lapian et al., 2013). Higher CW generally shows better feed efficiency and greater potential profitability for producers. However, extremely high CW can lead to increased fat deposition, which is undesirable in modern pork production systems prioritizing lean meat. The ANOVA showed that providing STW at 0 %, 4 %, 8 %, and 12 % in the ration had a significantly different effect ($p<0.05$) on CW. Based on the Least Significant Different (LSD) test results, the 12 % treatment resulted in a significantly higher SW ($p<0.05$) than the levels of 0 %, 4 %, and 8 %. This is due to high CW, which the SW of the pigs influences, but with high SW, it does not always produce high CW. This is in line with the findings that carcass weight growth increases with age (Malgwi et al., 2021), and carcass weight increases with higher age of livestock over a certain period, caused by the growth and development of organs (Rodrguez-Snchez et al., 2010).

This is in line with previous research that showed that achieving feed efficiency in pigs at an optimal level can produce better profits for farmers (Van Wijk et al., 2005). Feeding and rearing affect pigs' growth performance and carcass composition through the relative growth deposition of fat and lean tissue (Lebret, 2008). The feed and the corresponding daily intake can influence nutrient digestibility, transit time, metabolic rate, and weight equilibrium (Chassé et al., 2021). Based on the data in Table 4, treatment R3 (12% STW flour + 8% concentrate) maximized carcass weight. Previous research produced various results where the use of other substitute materials also increased carcass weight (Biswas & Kim, 2022; Chassé et al., 2021; Wahyono et al., 2023).

Carcass Length (CL)

CL is an important characteristic related to the overall body composition of pigs. Table 3 shows that carcass length ranges from 89.6 cm to 94.0 cm. Longer carcass is often associated with a higher proportion of lean meat, specifically in the loin and abdomen. Previous research confirmed the same results (Carabús et al., 2017; Casas, G.A. and Stein, 2016). However, a long carcass can sometimes be associated with reduced muscle (Rossi et al., 2013).

The ANOVA shows that providing STW at 0 %, 4 %, 8 %, and 12 % did not affect CL ($p>0.05$). This is presumably because CL is more influenced by the growth of the vertebrae (*Columna vertebralis*), which differs between the front border of the first rib and the back thigh bone. The tissue grows early; hence, feed or other treatments do not easily influence the linear size during growth (Skinner et al., 2014). Nonetheless, CL is intricately linked to SW, wherein superior SW corresponds to elevated CL (Li et al., 2021). The results differ because the SW and CW vary, but the carcass length is the same. This is because CL is the growth of the vertebral segments, starting from the first thoracic vertebral column to the last sacral vertebrae on the os coxae (Guo et al., 2017). Therefore, CL was not influenced by any treatment during the postnatal growth of the animal because the tissue grew and developed early (Rohrer et al., 2015).

Carcass Percentage (CP)

The average CP obtained from the provision of skipjack tuna waste at 0 %, 4 %, 8 %, and 12 % in the ration ranged from 69.95 % - 73.66 % with a general average of 72.09 % and a SW of 111.8-121.4 kg. This result differs from the finding stating that the marketed body weight range was 90-110 kg with a general average of 94.02 kg and CP of 71.51 ± 4.77% (Wang et al., 2022).

The ANOVA showed that the provision of STW at 0 %, 4 %, 8 %, and 12 % as a partial substitute for concentrate in the ration had a different but insignificant effect ($p>0.05$) on CP. In other words, all the treatments had the same impact on CP.

CP is intricately linked to CW and is contingent upon the SW (Purnamartha et al., 2014). This result did not align with the statement because the CW obtained increased in line with the treatment (0 %, 4 %, 8 %, and 12 %) while the CP was the same. Differences in the weight of heads, blood, feathers, abdominal cavity contents, and chest cavity contents can cause disparity (Álvarez-Rodríguez & Teixeira, 2019). The increase in CP with age is caused by a rise in hormones that affect the growth of bones, muscles, and fat during growth, thereby improving body weight, CW, and CP (Li et al., 2021).

Loin Eye Area (LEA)

The average LEA obtained from STW as a substitute for the ration ranged from 42.32-48.49 cm^2, with a general average of 45.18 cm^2. The ANOVA showed that the addition of STW had a significantly different effect ($p<0.05$) on LEA (Table 3). The LSD test showed that the treatment without STW (control) had a lower than R1 (4%), R2 (8%) and R3 (12%). This is in line with previous research (Purnamartha et al., 2014; Sinaga et al., 2020). This can be attributed to STW's high protein content, which constitutes 60-70% of its dry weight. Protein content has an excellent amino acid profile, including essential amino acids needed for muscle synthesis and growth (Howe et al., 2002), showing great potential for the growth and formation of loin eye muscles (Thuy et al., 2010). This can cause a larger LEA in pigs fed with STW.

The size of the LEA increases with pigs' growth and body weight. Growth occurs mainly in the muscles during the starter and grower phases (Tuan & Ogle, 2019). In fast-growing pigs, the most significant accumulation of muscle meat occurs in the finisher phase. Muscle meat is mainly made of protein. Hence, sufficient feed protein should be supplied to pig feed for maximum LEA growth. Key factors affecting LEA growth are the protein content (amino acid balance) of the ration, genetics, health during the starter and grower periods, and CW (Ardestani et al., 2021).

Backfat Thickness (BFT)

The average BFT obtained from STW fed at 0 %, 4 %, 8 %, and 12 % as a partial substitute for concentrate ranged from 3.28-3.58 cm with a general average of 3.39 cm. This average shows a tendency for an increase in BFT compared to R0. However, based on the ANOVA, the effect of treatment on BFT was not significantly different ($p>0.05$) (Table 3).

Backfat in pigs is formed as an energy reserve and thermal insulator. The accumulation is influenced by genetic factors, nutrition, rearing management, and hormones (Fang et al., 2014). Despite the substitute of concentrate, the overall nutrient composition of the feed remained well maintained. This ensures that no deficiency or imbalance of nutrients can affect metabolism and backfat deposition. Additionally, pigs are adaptable to changes in feed composition. With constant nutritional needs supply, pigs can adapt without showing significant differences in backfat accumulation. Genetics, rearing management, and physiological status may dominate in determining BFT (Skinner et al., 2014). This is presumably why differences in feed treatments do not have a significant effect. The rearing system with individual cages, ration composition, feeding methods, cages, temperature, and humidity following the requirements may cause excessive fat accumulation. High energy content and sufficient methionine doses in the ration lead to high body fat deposition and decreased protein and water content (Sinaga et al., 2020). Fat accumulation occurs at every age level when the energy in the body exceeds the basic living needs and growth (Dunker et al., 2007). SW also influences carcass fat, while the growth rate is influenced by protein. Feed containing 20% protein compared to 23% produced different CW and CP but the same BFT of 3.3 cm (Ardestani et al., 2021).

Skipjack Tuna Waste (STW) Performance

The R3 (12% STW flour + 8% concentrate) was identified as the most effective treatment for SW, CW, and LEA variables because each of these variables produces the highest value in treatment R3, namely 121.40 kg, 89.40 kg, and 48.49 cm^2 (Table 3), meaning that partial substitution of concentrate using STW can produce a more extensive and potentially valuable carcass. However, the use of STW is expected to provide nutritional benefits by reducing dependency on concentrate import, which in turn lowers the feed cost. In this way, reusing tuna waste rather than disregarding it may also pose several positive impacts on the environment.

CONCLUSION

In conclusion, providing STW as a concentrate substitution with levels of 0% (R0), 4% (R1), 8% (R2), and 12% (R3) had different impacts on each of the SW, CW, and LEA variables, but not on the CP, CL, and BFT. The R3 treatment showed the most effective ration performance on all carcass quality variables, and this treatment can be recommended as the best ration composition for partial concentrate substitution.

This means that STW can be considered a partial substitute for a concentrate from the viewpoint of a positive environmental effect due to waste reduction and resource efficiency since it bears no negative impact. It also helps decrease this footprint by lowering the demand for land and water resources related to the production of traditional feeds.

However, this research still has some shortcomings, primarily related to the variables discussed; therefore, more research is needed to assess the environmental and economic aspects of using STW as pig feed.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

MTRL Conceived the idea, designed the project, Methodology, and Formal Analysis. CAR: Validation, Investigation, and helped Formal Analysis. DSIS: Performed statistical analysis, Writing-original draft, Writing-review & editing. All authors had approved the final version.

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