Utilization of fermented chicory and cabbage waste in feed to improve growth performance of giant gourami (*Osphronemus goramy*)

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Abstract. This study aims to analyze the utilization of fermented chicory and cabbage waste (FCCW) as a fish meal alternative in the feed of giant gourami (*Osphronemus goramy*). Five feeds were formulated to include 25% crude protein. The control feed (P0) consisted of 100% fish meal, while feeds P1, P2, P3, and P4 incorporated 15%, 25%, 35%, and 45% FCCW, respectively, as substitutes. Juvenile giant gourami, with a mean body weight of 2.09±0.04 g, were stocked into floating net cages measuring 1x1x1 m at a density of 20 fish per cage. The experimental feeds were administered three times a day - at 8:00 AM, 12:00 PM, and 5:00 PM - until satiation for 56 days. The results showed statistically significant differences ($p < 0.05$) in weight gain, feed intake, feed efficiency, specific growth rate, protein intake, and net protein utilization among the feeds. However, no significant differences ($p > 0.05$) were observed in the fish's survival rate in all treatments. Thus, it was concluded that using 45% FCCW can effectively substitute fish meal in the feed of giant gourami.
Key Words: cabbage waste, chicory waste, giant gourami, substitute, utilization.

Introduction. Feed is a crucial component in aquaculture for promoting growth. In Indonesia, the feed often relies on imported fish meals as the main protein source. These imported meals typically have better quality than local ingredients, making them relatively expensive. To address the issue of high costs, it is possible to substitute imported fish meals with locally sourced raw materials that are both cost-effective and good quality.

Chicory (*Brassica pekinensis* L.) and cabbage (*Brassica oleracea*) waste are among the alternative materials that meet the criteria of high quality, abundant availability, waste utilization, and low cost. Chicory contains 12.64-23.50% crude protein, vitamins C and K, and 3200-3400 kcal kg^{-1} energy, while cabbage contains 23.87% crude protein, 1.75% lipid, and 39.27% carbohydrates (Muktiani et al 2007). However, the high crude fiber content of cabbage and chicory waste, ranging from 20.76 to 29.18%, limits their digestibility and optimal consumption by fish (Muktiani et al 2007).

To improve digestibility, fermentation technology using cellulolytic bacteria from cow rumen liquor is needed to break down the lignocellulosic and lignohemicellulose complexes. This process results in materials that are more easily digestible (Hernawati et al 2010). Adelina et al (2019) found that fermenting *Lemna minor* leaves with cow rumen liquor cellulolytic bacteria decreased crude fiber content by 10%, increased protein content by 5%, improved feed digestibility by 10.89%, and enhanced the aroma and flavor of the ingredients.

The purpose of this research was to evaluate the utilization of fermented chicory and cabbage waste as an alternative protein source for fish feed. The study was conducted on juvenile giant gourami (*Osphronemus goramy*), a freshwater fish with high economic value and significant market demand. Although giant gouramies are omnivorous, they predominantly exhibit herbivorous feeding behavior, showing a preference for plant-based feed ingredients (Suharyanto & Febrianti 2015). Therefore, this study aimed to determine the optimal amount of fermented chicory and cabbage flour that can be effectively used to enhance feed efficiency and growth in giant gourami.

Material and Method

Time and location. This research was conducted in January-August 2023 at the Experimental Pond and Fish Nutrition Laboratory, Faculty of Fisheries and Marine, University of Riau, Pekanbaru.

Fermentor preparation. Fermentors were prepared by following the methods described by Safir et al (2023), namely: 1). Add 5 L of water to a 10 L plastic bucket, 2). Add 100 g of cow rumen liquor to the bucket, 3). Dissolve 200 g of substrate in 500 mL of water, then add this solution to the bucket and stir until well mixed, 4). Tightly close the bucket and incubate for 48 hours, 5). Observe bacterial growth, indicated by the presence of white foam floating on the surface of the liquid, 6). Collect the bacteria by filtering the mixture twice using four layers of gauze. The filtrate obtained is used as the fermentor.

Provision of chicory and cabbage waste flour. The waste from chicory and cabbage was collected from vegetable traders and washed thoroughly to remove any attached dirt. The chicory and cabbage were then separated from other materials. The vegetables were cut into small pieces, dried, and ground using a flour machine. This process was carried out to obtain chicory and cabbage flour, which were then mixed in a 50:50 proportion, creating a blend suitable for use as feed ingredients.

Fermentation of chicory and cabbage waste flour. The chicory and cabbage waste flour were steamed for 15 minutes to kill pathogenic microbes, then cooled. Subsequently, the flour was mixed evenly with the fermentor at a ratio of 25% fermentor per kilogram of flour. The mixture was transferred into a tightly sealed bucket and incubated for 5 days (120 hours) to allow fermentation (Murni et al 2017). After five days, the bucket was opened, and the fermented material was dried and ground into flour, making it ready for use as feed ingredients.

Feed preparation and analysis. All feed ingredients, including fermented chicory and cabbage wastes (FCCW), soybean meal, fish meal, wheat flour, mineral mix, vitamin mix, fish oil, and chromic oxide, were procured from a nearby feedstuff supplier. Based on the formulations provided in Table 1, the ingredients were meticulously weighed and thoroughly mixed until achieving a homogeneous blend. The mixture was then formed into pellets and dried at 60°C in an oven. The resulting dry pellets were subjected to proximate analysis using the methods outlined in AOAC (2012). The results of the analysis are shown in Table 1.

Experimental design. A completely randomized design (CRD) with 3 replications was used in this study. Five feeds were formulated to include 25% protein. The treatment feeds were as follows: P0 (0% FCCW) consisting of 100% fish meal, P1 (15% FCCW), P2 (25% FCCW), P3 (35% FCCW), and P4 (45% FCCW).

Feeding trial. Juvenile of giant gourami, with an initial mean weight of 2.09±0.04 g, were acclimatized to commercial feed for approximately 7 days before the feeding trial began. A total of 300 fish were randomly distributed into floating net cages measuring 1 x 1 x 1 m^3, with a stocking density of 20 fish per cage. The experimental feeds were administered three times a day, at 8:00 AM, 12:00 PM, and 5:00 PM, for a duration of 56 days, until satiation was reached. In the event of fish mortality during the trial, the number of deaths was recorded to obtain survival data. After 60 days, two fish were randomly selected from each cage and anesthetized using MS-222 (tricaine methanesulfonate). The intestines of the selected fish were carefully removed and frozen at -80°C for subsequent histological analysis. Intestine removal was conducted 18 hours after the consumption of the last feed.

Table 1

Formulation and proximate composition of experimental feeds

Ingredients	*P0 (FCCW 0)*	*P1 (FCCW 15)*	*P2 (FCCW 25)*	*P3 (FCCW 35)*	*P4 (FCCW 45)*
Fish meal	52.0	35.5	28.5	22.0	12.0
FCCW[1]	0.0	15.0	25.0	35.0	45.0
Soybean meal	25.0	29.0	29.5	30.0	32.0
Wheat flour	17.0	14.5	11.0	7.0	5.0
Vitamin mix[2]	2.0	2.0	2.0	2.0	2.0
Mineral mix[3]	2.0	2.0	2.0	2.0	2.0
Fish oil	2.0	2.0	2.0	2.0	2.0
Chromic oxide	0.5	0.5	0.5	0.5	0.5
Proximate compotition (%)					
Crude protein	30.20	30.35	30.68	30.81	31.10
Crude lipids	4.57	4.39	4.15	3.90	3.68
Moisture	8.38	8.14	7.77	7.52	7.36
Ash	4.35	4.39	3.81	3.35	3.15
Crude fiber	11.15	10.40	9.90	8.65	7.46
NFE[4]	41.35	42.33	43.69	45.77	47.25
Chromic oxide	0.5	0.5	0.5	0.5	0.5

[1] Fermented chicory and cabbage waste; [2] Vitamin mix (mg/100 g diet): thiamin 5.0, riboflavin 5.0, Ca-pantothenate 10.0, niacin 2.0, pyridoxin 4.0, biotin 0.6, folic acid 1.5, cyanocobalamin 0.01, inositol 200, ρ-aminobenzoic acid 5.0, menadion 4.0, vit A palmitate 15.0, chole-calciferol 1.9, α-tocopherol 20.0, Cholin Chloride 900.0; [3] Mineral mix (mg 100 g^{-1} diet): KH_2PO_4 412, $CaCO_3$ 282, Ca (H_2PO_4) 618, $FeCl_3.4H_2O$ 166, $ZnSO_4$ 9.99, $MnSO_4$ 6.3, $CuSO_4$ 2, $CuSO_4.7H_2O)$ 0.05, KJ 0.15, Dextrin 450, Cellulose 553.51; [4] NFE = nitrogen-free extract; calculated = 100 - (%CP + %CL + %moisture + %ash + %CF).

Measurement of water quality parameters. To evaluate the water quality in the floating net cages, various parameters including pH, ammonia, temperature, and dissolved oxygen (DO) were measured. pH, DO, and ammonia levels were assessed at the beginning, middle, and end of the study. Temperature readings were taken daily at 08:00 AM, 12:00 PM, and 5:00 PM using a thermometer. pH was measured using a pH meter, while DO levels were determined with a DO meter. Ammonia levels were assessed through titration.

Digestibility study. For the digestibility study, 20 juvenile of giant gourami with a mean weight of 2.09±0.04 g were distributed among 10 aquariums. One hour after feeding, any uneaten feeds were collected. Additionally, fresh feces were gathered through siphoning approximately 4 to 5 hours after feeding and each morning before the feeding time. The fecal samples were combined until an adequate quantity was obtained for chemical examination. Subsequently, the samples were dried in an oven at 60°C, ground using a laboratory grinder, and stored in a freezer for subsequent analysis. Finally, the protein and chromic oxide content of both the feces and feed were analyzed according to the procedures outlined in AOAC (2012).

Fish intestine histology. Histological analysis was conducted to examine the intestinal wall structure following the administration of a test feed containing FCCW. After completing the maintenance period, the intestines of the test fish from each treatment were removed and prepared for histological examination using an Olympus binocular microscope model CX 21. A comparison of observations was then carried out to identify any discrepancies among the treatments regarding the presence of congestion, goblet cells, and hemorrhage in the intestinal tissues.

The samples were prepared according to the method outlined by Dellman et al (1992). Fish were dissected, and the intestines were collected and sliced to a thickness of

0.5 cm. The slices were then fixed for 24 hours in a 10% formalin solution. To initiate dehydration, the samples were placed sequentially in bottles containing 30%, 50%, 70%, 90%, and 100% alcohol for 45 minutes each. This process aimed to remove the moisture content from the cells and tissues, replacing it with alcohol. Finally, the samples were immersed in xylene 1 and 2 for 45 minutes each to facilitate the dealcoholization process.

Data analysis. The experimental data were collected and subjected to statistical analysis using analysis of variance (ANOVA) with 5 treatments and 3 replications. Duncan's Multiple Range Test was applied to observe mean differences. Alphabetical notations (e.g., a, b, c) were used to indicate variations at $p < 0.05$ for the feed and protein digestibility data.

Results and Discussion

Growth and survival rate of giant gourami. The growth performance and survival rate of giant gourami were evaluated after being fed feeds comprising different levels of FCCW for a 56-day culture period, as demonstrated in Table 2. At the commencement of the study, the mean initial body weight of the fish ranged from 2.04 to 2.11 g. No significant differences ($p > 0.05$) were observed among all the experimental feeds at this stage.

Table 2

Effects of experimental feeds on growth and survival of giant gourami

Parameters	*P0 (FCCW 0)*	*P1 (FCCW 15)*	*P2 (FCCW 25)*	*P3 (FCCW 35)*	*P4 (FCCW 45)*
Initial weight (g)	2.10 ± 0.05^a	2.10 ± 0.01^a	2.04 ± 0.04^a	2.11 ± 0.01^a	2.11 ± 0.01^a
Final weight (g)	7.40 ± 0.01^a	8.52 ± 0.02^d	9.99 ± 0.01^e	8.42 ± 0.02^c	7.51 ± 0.01^b
Weight gain (g)	5.31 ± 0.05^a	6.41 ± 0.02^d	7.94 ± 0.04^e	6.31 ± 0.02^c	5.40 ± 0.02^b
SGR (% day^{-1})	2.25 ± 0.04^a	2.50 ± 0.01^b	2.83 ± 0.03^c	2.47 ± 0.01^b	2.27 ± 0.01^a
Survival rate (%)	98.67 ± 0.00^a	98.67 ± 2.31^a	100 ± 0.00^a	98.67 ± 2.31^a	100 ± 0.00^a

Data values are the mean and standard deviation. Means with different superscripts (a, b, c, d, e) in the same row are significantly different ($p < 0.05$).

After 56 days of feeding, the final weight of the fish increased at a range of 7.40-9.99 g, showing significant differences ($p < 0.05$) among the feeds. Fish feed containing 25% fermented chicory and cabbage waste (FCCW 25) produced the best mean weight gain in giant gourami (7.94±0.04 g), significantly higher ($p < 0.05$) than the value obtained from other diets. The lowest average weight gain was identified in P0, FCCW 0 (5.31±0.05 g), and this was significantly different ($p < 0.05$) from the other treatments. Specific growth rate (SGR) also showed significant differences ($p < 0.05$) among the treatments. Fish feed containing 25% fermented chicory and cabbage waste (FCCW 25) exhibited a significantly higher SGR of 2.83±0.03%. The lowest rate was observed in P0, FCCW 0 (2.25±0.04%), although not significantly different ($p > 0.05$) compared to P4, FCCW 45 (2.27±0.01%).

The survival rate was notably high in the feeding trial, with all treatments exceeding 97%. Dietary treatments did not have a significant impact on the survival rate ($p > 0.05$). This study demonstrated that the utilization of FCCW in the feed can be effectively utilized by giant gourami for growth and survival.

Protein utilization and feed efficiency. Table 3 presents the feed efficiency and protein utilization of experimental diets on giant gourami. Significant differences in feed intake were observed ($p < 0.05$), although not in all treatments. However, no significant differences ($p > 0.05$) were observed among the fish fed with P0 (549.31± 6.22 g), P3 (564.29±3.98 g), and P4 (554.87±1.12 g). Those given a feed containing 25% fermented chicory and cabbage waste (FCCW 25) exhibited higher feed efficiency (31.72±0.21%) compared to other treatments, which were significantly different (p <

0.05) from each other. Furthermore, this study demonstrated that as the FCCW inclusion in the feed increased, the feed efficiency and intake decreased. This could be attributed to the palatability and digestibility of the fish feed.

The analysis of protein intake revealed significant differences ($p < 0.05$) among the feeds (P0-P4), although not in all treatments. No significant differences ($p > 0.05$) were found in the fish fed with P1 (173.49±1.40 g ind^{-1}), P3 (173.86±1.23 g ind^{-1}), and P4 (172.56± 0.35 g ind^{-1}). Moreover, P0 exhibited the lowest digestibility, while P2 demonstrated the highest digestibility, and both treatments were significantly different compared to the other treatments ($p < 0.05$). This study found that the FCCW inclusion in the feed was inversely proportional to protein digestibility.

The protein efficiency ratio (PER) in the fed fish exhibited significant differences ($p < 0.05$), although not in all treatments. Fish fed with 25% fermented chicory and cabbage waste (FCCW 25) exhibited significantly higher PER (1.03±0.01) than the other feeds, while P0 (FCCW 0) had the lowest value (0.76±0.01). Regarding the apparent net protein retention (ANPR) in the fed fish, significant differences ($p < 0.05$) were found across all experimental feeds. The highest and lowest levels were discovered in treatments P2 (81.90±0.51%) and P0 (61.73±1.04), respectively.

Table 3

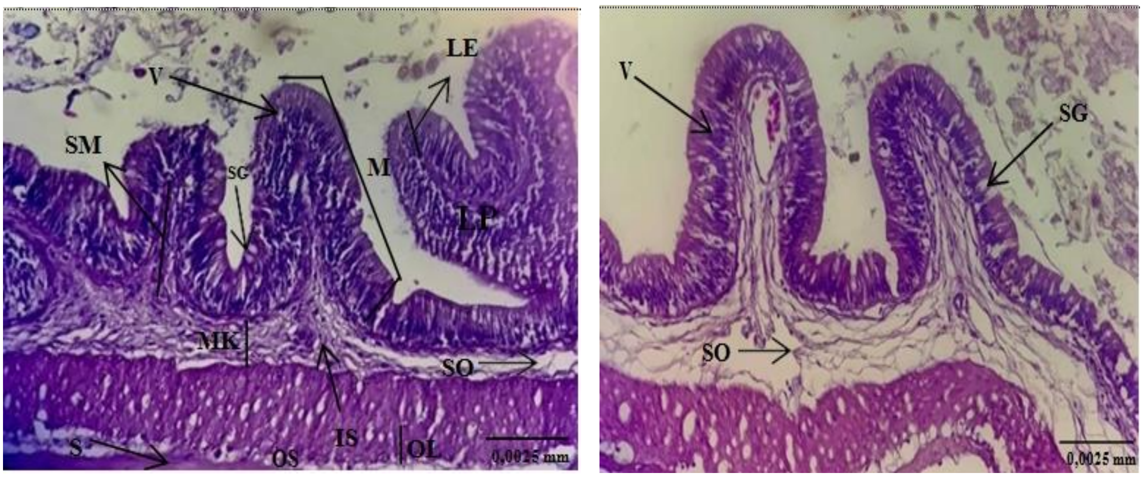
Protein utilization and feed efficiency of giant gourami

Parameters	*P0 (FCCW 0)*	*P1 (FCCW 15)*	*P2 (FCCW 25)*	*P3 (FCCW 35)*	*P4 (FCCW 45)*
Total feed intake (g)	549.31±6.22^{a}	571.62±4.61^{b}	625.99±1.43^{c}	564.29±3.98^{ab}	554.87±1.12^{ab}
Feed efficiency (%)	23.53±0.98^{a}	27.91±0.10^{c}	31.72±0.21^{d}	27.80±0.14^{c}	24.51±0.26^{b}
Protein intake (g ind^{-1})	165.89±1.88^{a}	173.49±1.40^{b}	192.05±0.44^{c}	173.86±1.23^{b}	172.56±0.35^{b}
Protein digestibility (%)	67.84.±1.46^{a}	76.36±1.10^{c}	81.21±0.27^{d}	78.15±0.98^{c}	73.84±1,02^{b}
Protein efficiency ratio	0.76±0.01^{a}	0.91±0.02^{b}	1.03±0.01^{c}	0.89±0.03^{b}	0.78±0.00^{a}
Apparent net protein retention (%)	61.73±1.04^{a}	71.32±0.68^{c}	81.90±0.51^{e}	73.30±0.27^{d}	64.23±0.28^{b}

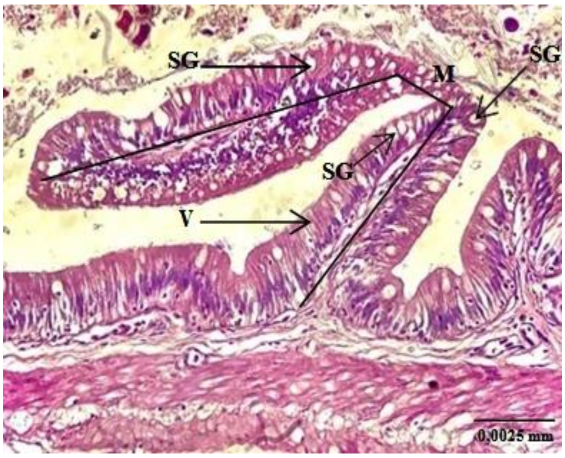
Data values are the mean and standard deviation. Means with different superscripts (a, b, c, d, e) in the same row are significantly different ($p < 0.05$).

Intestine histology. Figure 1 illustrates the intestinal histology of giant gourami fed with FCCW. Based on the observations, each fish intestine consists of villi, mucosal tunica, submucosal tunica, muscular tunica, lamina epithelia, lamina propria, circular muscles, elongated muscles, muscle cell nuclei, and muscle fibers.

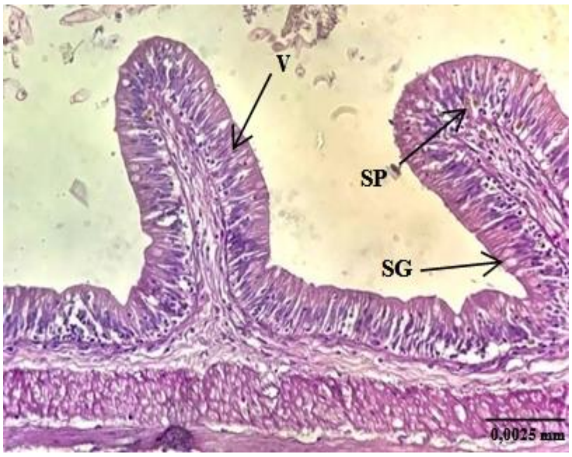
In the P0 treatment, fish intestines appear to have villi, but goblet cells were not observed. In P1, hollow muscle fibers and few goblet cells were present. P2 exhibited longer mucosal tunica and intestinal villi with more goblet cells. However, in the fish intestines from the P3 (FCCW 35) and P4 (FCCW 45) treatments, undigested remnants of the feed were detected, indicating relatively challenging digestion. Additionally, fish given P4 experienced damaged intestines with irritating walls.



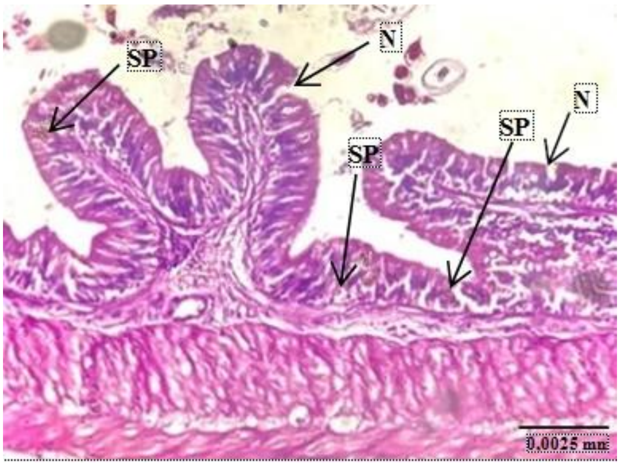
P0 (FCCW 0) P1 (FCCW 15)



P2 (FCCW 25)



P3 (FCCW 35)



P4 (FCCW 45)

Figure 1. The intestinal histology of giant gourami fed with FCCW (V = villi, M = mucosal tunica, SM = submucosal tunica, MK = muscular tunica, S = serous tunica, LE = lamina epitelia, LP = lamina propria, SG = goblet cells, OS = circular muscle, OL = elongated muscle, IS = muscle cell nucleus, SO = muscle fibers, SP = feed residue, magnification 400x).

Water quality. Table 4 displays the water quality measurements obtained during the experimental period. There was no significant fluctuation in water temperature during the maintenance of giant gourami. The temperature, pH, DO, and ammonia concentrations ranged from 26.5 to 26.8°C, 6.8 to 6.9, 4.4 to 4.5 mg L^{-1}, and 0.03 to 0.05 mg L^{-1}, respectively. These measurements fell within the desirable ranges for the successful culture of giant gourami in this study, indicating suitable water quality conditions were maintained (Sitanggang & Sarwono 2007).

Table 4

Water quality parameters during the feeding trial

Parameters	*P0 (FCCW 0)*	*P1 (FCCW 15)*	*P2 (FCCW 25)*	*P3 (FCCW 35)*	*P4 (FCCW 45)*
Temperature (^{0}C)	26.5±0.6	26.8±0.8	26.4±0.5	26.7±0.5	26.6±0.7
pH	6.8±0.5	6.8±0.7	6.9±0.1	6.8±0.7	6.8±0.6
DO (mg L^{-1})	4.5±0.3	4.4±0.4	4.5±0.4	4.5±0.4	4.4±0.5
Ammonia (mg L^{-1})	0.04±0.02	0.03±0.02	0.04±0.02	0.05±0.01	0.05±0.02

Cost of experimental diets. Table 5 presents the total cost of raw materials for the feeds, ranging from IDR 12,215 to 14,845 per kg. The results indicate that the amount of FCCW was directly proportional to the cost. The control feed (FCCW 0) amounted to IDR 14,845 per kg. However, when replaced with fermented chicory and cabbage waste at 15%, 25%, 35%, and 45% of fish meal, the cost was reduced to approximately IDR 992.5, 1,510, 2,000, and 2,630 per kg, respectively. It is noteworthy that the feed utilization and growth were likely to be higher in the feed comprising 25% FCCW. Therefore, it is recommended as a replacement feed for giant gourami.

Table 5

Cost of giant gourami experimental feeds

Raw material	*Price*	*P0 (FCCW 0)*	*P1 (FCCW 15)*	*P2 (FCCW 25)*	*P3 (FCCW 35)*	*P4 (FCCW 45)*
Fish meal	12,000	6,240	4,260	3,420	2,640	1,440
FCCW[1]	5,000	0	750	1,250	1,750	2,250
Soybean meal	10,000	2,500	2,900	2,950	3,000	3,200
Wheat flour	6,500	1,105	942.5	715	455	325
Vitamin mix	100,000	2,000	2,000	2,000	2,000	2,000
Mineral mix	100,000	2,000	2,000	2,000	2,000	2,000
Fish oil	50,000	1,000	1,000	1,000	1,000	1,000
Total (IDR kg^{-1})		14,845	13,852.5	13,335	12,845	12,215

Note: Official exchange rate: P0-P4 14,929 per US$.

Chicory and cabbage waste emerge as viable alternatives for fish feed due to their rich nutrient content, widespread availability, and cost-effectiveness. Rety (2016) demonstrated that utilizing 30% chicory and 30% green cabbage yielded optimal results for Nile tilapia (*Oreochromis niloticus*). Similarly, in this study, the highest SGR and weight gain of 2.83±0.03% and 7.94±0.04 g, respectively, were observed in the P2 treatment. These findings suggest efficient utilization of protein in the feed by fish in this treatment, contributing to their increased body weight through protein retention. This aligns with Adelina et al (2021), who reported that energy from feed is primarily allocated to maintenance, with the remainder contributing to growth.

Santoso & Manan (2015) highlighted that vegetable waste can serve as suitable feed for Nile tilapia. Additionally, Hasan et al (2014) found that incorporating 20% chicory waste into feed led to optimal growth of gourami (*Helostoma temminckii*). Similarly, Susangka et al (2006) reported that replacing 20% of feed with vegetable waste did not compromise the growth of Nile tilapia. These studies collectively underscore the potential of chicory and cabbage waste as effective and sustainable components of fish feed, supporting growth and nutritional needs in aquaculture practices.

In treatment P0, the gourami weight exhibited the smallest increase of 5.31± 0.05 g, which was found to be statistically significant ($P<0.05$). However, the SGR in this treatment (2.25±0.04%) did not exhibit a statistically significant difference ($p > 0.05$) compared to P4 (2.27±0.01%). Furthermore, fishes in P0 were less efficient in utilizing feed to improve their growth performance. Buwono et al (2021) noted that growth performance is influenced by the amount of feed protein consumed. The low SGR in P4 could be attributed to the fish's inability to utilize feed containing high amounts of FCWW, resulting in insufficient energy to support growth. Consistent with the findings of Hasan et al (2014), higher concentrations of chicory in feed lead to lower growth rates and SGR in Nile tilapia.

The amount of feed consumed by gourami ranged from 549.31 g to 625.99 g and differed between treatments. P0 and P2 had the lowest and highest consumed feed, respectively, but no statistically significant differences ($p > 0.05$) were identified compared to P3 and P4. The amount of feed consumed was directly proportional to the protein intake and feed efficiency. According to the results of this study, P2 and P0 treatments had the highest and the lowest feed efficiency of 31.72±0.21% and 23.53±0.98% respectively. This could be attributed to the optimal fermentation concentration of chicory and cabbage waste, which affected the digestibility and utilization of feed. The utilization of fermented chicory and cabbage waste in feed P3 and P4 was inversely proportional to the feed consumed by fish and efficiency. This was consistent with the findings of Adelina et al (2020), who reported that fermented chicken feather flour in feed was inversely proportional to consumption and efficiency. Belal (2005) and Ugwuanyi et al (2009) stated that the higher the feed efficiency value, the better the quality.

The digestibility of protein by gourami was relatively high, ranging from 67.84 to 81.21%, and differed significantly between treatments ($p < 0.05$). P0 exhibited the lowest protein digestibility, protein efficiency ratio (PER), and apparent net protein retention (ANPR), and showed significant differences from other treatments ($p < 0.05$). This could be attributed to the absence of FCCW, making digestion relatively difficult. According to NRC (1993), the digestibility level of a feed type depends on its quality, ingredient composition, and nutritional content. FCWW using cow rumen fluid produces digestive enzymes that hydrolyze complex compounds such as proteins, facilitating protein digestion. Digestibility is directly proportional to the availability of nutrients that can be utilized for growth and maintenance. P2 had the highest protein digestibility at 81.21±0.27%. NRC (1993) stated that the digestibility value in fish ranges from 75 to 95%. Therefore, FCWW at 25% concentration was found to be optimal.

The digestibility of protein in fish is associated with the structure of their intestines. In P0, a normal structure was observed, with no visible goblet cells in the intestinal villi. According to Purbomartono et al (2004), goblet cells facilitate the process of feed digestion, and their abundance is directly proportional to digestibility. Fish intestines in the P1 treatment exhibited less frequent muscle fibers, giving them a cavity-like appearance. This could be attributed to the response of the intestinal villi to digestion and absorption. Only a few goblet cells were observed in the intestine, indicating relatively efficient feed digestion, as shown in Figure 1.

Fish intestines in the P2 treatment exhibited longer mucosal tunica and intestinal villi with more goblet cells, indicating a more optimal process of feed digestion and absorption. The data in Table 3 also showed higher feed digestibility in P2 compared to other treatments. Nurhayati et al (2021) noted that the width, height, and length of villi influence the process of feed absorption. Additionally, Sariati et al (2019) reported that goblet cells protect the intestinal mucosa and increase mucus secretion.

The utilization of chicory and cabbage waste in P3 and P4 treatments resulted in a smaller number of villi and goblet cells. As shown in Table 3, low protein digestibility was observed, indicating suboptimal digestion and absorption of feed by the intestine. Firdus et al (2020) mentioned that intestinal length and the number of microvilli affect absorption. Fish intestines in the P4 treatment appeared irritated or eroded, leading to imperfect villi structure. Irritation or erosion can cause partial loss of epithelium in the intestinal lining, resulting in thinner mucosa. This erosion disrupts nutrient absorption from the feed, leading to malnutrition in fish and potentially even death (Plumb 1994).

Conclusions. This study found that substitution of 25% fermented chicory and cabbage waste effectively replaced fish meal in the feed of giant gourami. The fish exhibited proper digestion and absorption of the feed, resulting in efficient utilization of nutrients and promoting optimal growth. The substitution of 25% fermented chicory and cabbage waste for fish meal in giant gourami feeds offers a sustainable, cost-effective, and environmentally friendly alternative that can be further explored and potentially expanded to benefit the broader aquaculture industry.

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Conflict of interest. The authors declare that there is no conflict of interest.

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