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COST-BENEFIT ANALYSIS AND GROWTH EFFECTS OF PELLETED AND UNPELLETED ON-FARM FEED ON AFRICAN CATFISH (*CLARIAS GARIEPINUS* BURCHELL 1822) IN EARTHEN PONDS

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ABSTRACT

Fish feed constitutes 40-60% of the total operational costs of a fish farm. Commercial feeds are often too expensive for rural fish farmers. Consequently, farmers use non-conventional and locally available fish feed ingredients including agro-industrial by-products. These feeds have not led to increased pond productivity due to poor processing, higher fibre content, and anti-nutritional factors that limit nutrient bio-availability. Farmers have not embraced processing of fish feeds because the cost-effectiveness of processing has not been clearly demonstrated. The African catfish (*Clarias gariepinus*) is an important farmed fish in sub-Saharan Africa hence the need for research on its nutrition and growth performance. The growth performance and cost-benefit of using pelleted diets formulated from locally available feed ingredients on *C. gariepinus* were evaluated in a rural African setting. The experiment included diets that differed in the ingredients and form used (pelleted and un-pelleted). Four isocaloric and isonitrogenous diets were formulated from freshwater shrimp (*Caridina nilotica*), rice bran (*Oryza sativa*) and wheat bran *(Triticum aestivum).* The diets were *C. nilotica* and wheat bran pelleted (CWBp), *C. nilotica* and wheat bran un-pelleted (CWBup), *C. nilotica* and rice bran pelleted (CRBp), and *C. nilotica* and rice bran un-pelleted (CRBup). The diets were fed to *C. gariepinus* fingerlings (mean initial weight 1.75±0.03g), in triplicates for 5 months. The pelleted diets showed significantly better performance (P<0.05) compared to the un-pelleted diets. Fish grew to a weight of 266.77±6.21g on CWBp, 224.9±3.91g on CRBp, 211.38±4.46g on CWBup and 190.87±4.47g on CRBup. Cost benefit analysis of the pelleted and un-pelleted diets indicated positive net returns of US$ 180.1 for CWBp, US$142.5 for CRBp, US$ 126.8 for CWBup and US$ 115.5 for CRBup. The CWBp had significantly higher net returns than the other diets. This paper demonstrates that although on-farm pelleting of diets adds extra cost of labour, pelleted diets are cost-effective and should be incorporated as an essential part of on-farm feed production.

Key words: Catfish, feed, pelleting, cost-effectiveness, pond

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INTRODUCTION

Fish feeds take up between 40-60% of the fish farm's production costs and is a major constraint to fish farming in resource poor regions [1]. Commercial fish feeds are, when available, expensive and beyond reach of most rural sub-Saharan Africa fish farmers who mostly live on less than a dollar a day. To reduce feed costs, the use of locally available fish feed ingredients including raw and/or semi-processed agro-industrial by-products is becoming common among eastern Africa fish farmers. Freshwater shrimps (*Caradina nilotica*) available in Lake Victoria as a by-catch of the Silver cyprinid (*Rastrineobola argentea*) fishery, and rice and wheat brans, by-products of rice and wheat milling industries are in use in the Lake Victoria basin. Brans have been recognized as important non-conventional feed resources for commercial production of fish feed [2]. However, these types of fish feeds have not led to increased productivity of farmed fish in sub- Saharan Africa. This may be attributed to poor processing, and higher fibre content limiting bio-availability and the presence of anti-nutritional factors within some plant feed ingredients [3]. Consequently, their nutrients may not be readily available to the fish [4]. For farmers to profit from utilizing the locally available fish feed ingredients, such feed must be presented in a form readily available to the fish.

African catfish (*Clarias gariepinus*) is second to Nile tilapia (*Oreochromis niloticus*) as one of the major cultured species in Kenya and most of the East African region [5, 6]. Feeding for *C. gariepinus* grown in ponds has mainly been through pond fertilization and application of brans and *C. nilotica*, either mixed or singly without formulation [7]. Due to the lack of fish feeds, many farmers find it difficult to maintain a crop of monoculture of *C. gariepinus*, and therefore it is mainly grown under polyculture with Nile tilapia. Lack of feeds for monoculture of *C. gariepinus* results in increased cannibalism in that fast growers prey on their slow growing siblings, leading to reduced fish survival, less pond recovery and poor yields.

Better growth of fish can be achieved through formulation and processing of diets with all the nutritional requirements [8, 9]. Although pelleting of feeds is generally accepted as a means of enhancing the economics of production by improving the growth and feed efficiency responses in animal feeds [10], data on the cost benefits of using processed fish feeds in catfish farming is lacking in the East African region and consequently, fish farmers are not consistent in using processed feeds. To increase fish farm profits, the cost of feed must be reduced. Considerable effort has focused on finding alternatives to fishmeal from both plant and animal protein sources [11, 12, 13]. Demonstration of the levels by which processing of fish feeds improves growth and profitability of fish farming in East Africa is not common in the literature. The present study was undertaken to determine the economic benefits and growth performance of *C. gariepinus* fed on formulated and pelleted diets.

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MATERIALS AND METHODS

Study area

The study was conducted at Bidii Self Help Group Fish Farm at Luanda in Vihiga County, Western Kenya (0° 20' 0" North, 34° 35' 0" East). *C. gariepinus* fingerlings of an average weight 1.75±0.03g were obtained from Lake Basin Development Authority (LBDA), Kibos Fish Hatchery. Fish were randomly placed in 12 pre-limed and fertilized experimental ponds measuring 150m^2 each. Each pond was stocked at the rate of 3 fish m^{-2}. Fish were acclimatized to the experimental conditions in ponds for 7 days while being fed a formulated 25% crude protein diet.

Preparation of test diet and feeding

Common feed ingredients, which are used as fish feed by fish farmers, were obtained from the local market. Four isonitrogenous, 25% crude protein diets were formulated using freshwater shrimps, *C. nilotica* with either wheat or rice bran. The feed ingredients were mixed and ground and were either pelleted before feeding the fish or used un-pelleted. They were designated, CRBp (*C. nilotica* + Rice bran, pelleted), CWBp (*C. nilotica* + Wheat bran, pelleted), CRBup (*C. nilotica* + Wheat bran, un-pelleted) and CWBup (*C. nilotica* + Wheat bran un-pelleted). The four diets were fed to the experimental fish in three replicate ponds for each dietary treatment. Fish were fed at 3% body weight twice a day at 1000 hours and 1600 hours for 5 months. The evening feeding time was according to Wurt [14] who indicated that in extensive systems, catfish tend to feed more aggressively between 1600 and 1900 hours. All the experimental ponds were fertilized weekly to stimulate growth of natural fish food organisms in the ponds using urea and diammonium phosphate (DAP) at the rates of 3 gm^{-2} and 2 gm^{-2}, respectively. Fertilization was done one week before fish were stocked and on a weekly basis after stocking.

Fish sampling

Fish were sampled once a month by use of a seine net. Representative samples of 30 fish were randomly taken from the seined fish and weight and length measurements taken for each treatment. After every sampling, new feeding rates were determined and feed rate adjusted according to the average weight determined from the sampled fish. At the end of 5 months, the ponds were completely drained, all the fish collected and measured for weight and total length. Weight was measured with a sensitive weighing balance readability 0.01g and length measured with a measuring board to the nearest 0.01 cm.

Water quality sampling

Water quality parameters - dissolved oxygen, temperature, conductivity and pH- were measured bi- weekly at 8.00 am, using a portable DO meter, YSI model 58 (Yellow Springs Instruments, OH, USA) and pH meter (Hanna Instruments, Model 8519N, Singapore).

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Growth rate

Specific growth rate (SGR) was calculated from the formulae; SGR = 100 ($\ln W_t$ – $\ln W_0$ / t) where: - (ln = Natural logarithm, W_0 = initial weight (g), W_t= final weight (g) and t = time (days).

Food conversion ratio

Food conversion ratio (FCR) was calculated by the formulae; FCR = feed intake (g)/body weight gain (g).

Condition factor

Condition factor was calculated from the formulae; CF = 100W (g)/ L (cm) ^{3}, where W= body weight and L= total length.

Net fish yield

Net fish yield was calculated as the difference between total weight of fish at harvest and total weight of fish at stocking.

Statistical analysis

Data collected from the experiment were subjected to one-way analysis of variance (ANOVA) test using the SPSS (Version 17.0) for windows, and where significant differences were indicated, means were tested by Tukey HSD test at the 5% level of significance.

Cost benefit analysis

Cost benefit analysis was conducted for each dietary treatment. Cost of feed ingredients was as per the existing market prices. The US dollar exchange rate against Kenya shillings was pegged at Kshs 80. The following information was used for the cost benefit analysis of each dietary treatment.

Input expenditure

- *C. gariepinus* fingerlings @ Kshs 3 × 450 per pond = Kshs 1350 per pond
- Cost of Rice bran @ Kshs 10× 140Kg^{-1}=Kshs1400 per pond
- Cost of Wheat bran @ Kshs 13× 140Kg^{-1}=Kshs1820 per pond
- Cost of *C. niloticus* @ Kshs 50× 40Kg^{-1}=Kshs2000 per pond
- Cost of fertilizer @ Kshs 60 ×5Kg^{-1}=Kshs 300 per pond
- Cost of pelletizing fish feed @ Ksh167 × 1 day=Kshs167 for making pellets
- Cost of feeding fish and pond management @ Kshs 1250 per month per pond
- Cost of packaging fish @ Kshs 25 Kg^{-1} of fish harvested
- Cost of transporting fish @ Kshs 25 Kg^{-1} of fish harvested.

Income from the fish yield at harvest

Fish harvested from each pond were pooled for each dietary treatment and sold at US$ 2.50 Kg^{-1}, the prevailing market price for 1 Kg of body weight of fresh unprocessed *C. gariepinus.*

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RESULTS

Fish growth data are presented in Table 1. Fish fed on CWBp grew to a mean of 266.8±4.21g; fish fed on CRBp to 224.9 ±3.91g, while fish fed on unpelleted diets CWBup and CRBup grew to 211.4 ±4.46g and 190.9±4.47g, respectively. There were significant differences (P<0.05) in fish growth among the dietary treatments. Fish fed on CWBp exhibited significantly higher mean final weight and specific growth rate (SGR) (P<0.05) compared with those fed on CRBp, CWBup and CRBup. The pelleted diets showed better growth performance compared to the unpelleted diets (Table 1). Fish fed on CWBp had significantly higher yields (P<0.05) and showed the lowest FCR of 2.45. There were no significant differences (P>0.05) in condition factor among all the dietary treatments. The growth of *C. gariepinus* was uniform for all the dietary treatments in the first month and, thereafter, there was differential growth up to the end of experimental period (Figure 1). The growth curve for the CWBp exhibited highest growth compared to the other dietary treatments with CRBup being lowest.

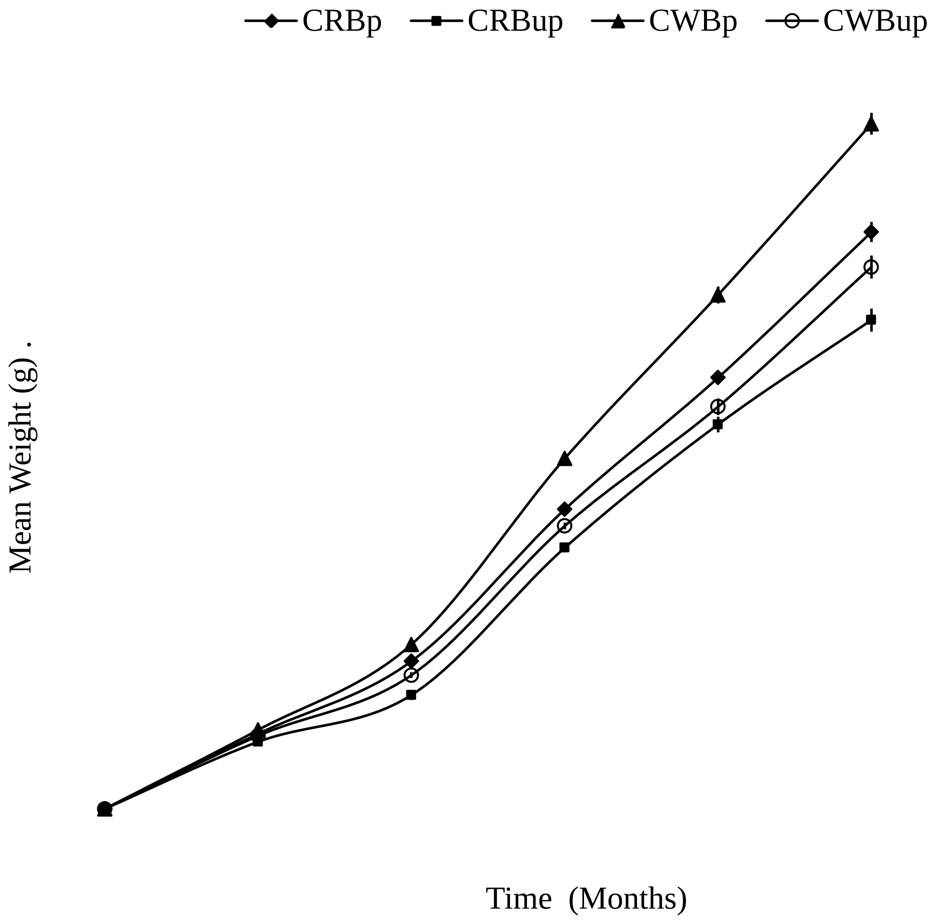

Figure 1: Mean weight (±SE) of *Clarias gariepinus* fed on different diets
**CRBp, pelleted C. nilotica and rice bran; CRBp, un-pelleted C. nilotica and rice bran; CWBp, pelleted C. nilotica and wheat bran; CWBup, un-pelleted C. nilotica and wheat bran.*

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Water quality parameters did not vary between dietary treatments. Dissolved oxygen from all the ponds ranged from 1.29 to 3.64 mg L^{-1} throughout the entire study period. There were no significant differences ($P>0.05$) between mean dissolved oxygen values among the treatments (Table 2).

The cost benefit analysis indicated positive net returns for all the experimental diets (Table 3). The pelleted feed, CWBp, demonstrated significantly ($P<0.05$) higher net returns US$ 180.06 than the other diets. CRBup had lowest net returns of US$ 111.50, which was significantly ($P<0.05$) lower than all the other treatments. The break-even yield was significantly lower ($P<0.05$) in CRBup and the CRBp compared to CWBp and CWBup. The gross fish yield differed significantly ($P<0.05$) among treatments. Fish fed on pelleted diets CWBp had the highest yield followed by fish fed CRBp, while fish fed on the un-pelleted CRBup had the lowest yield among the treatments.

DISCUSSION

In the present study, fish fed on pelleted diets exhibited significantly better growth than the other diets. Apart from the nutrient content of the feed, formulation and processing determine bio-availability of nutrients, feed acceptability, palatability and durability which affects growth performance of fish [15]. The better performance of pelleted feeds over the un-pelleted feed could be attributed to the fact that pelleted feed may have reduced feed wastage, uniform feed intake and destruction of growth inhibitors [16]. It has been noted that fish fed single type of food especially brans are usually the worst performers since such diets are neither complete nor balanced and do not supply all nutrients required by the fish [17]. In the present study, however, differences were observed among fish fed the same ingredients but in different forms indicating that pelleting had a significant role in improvement of overall productivity.

Feeding *C. gariepinus* on CWBp diet resulted in significantly higher final weight than those fed on CRBp, CRBup and CWBup. Individual mean weights recorded every month were found to be significantly higher when fish were fed on CWBp diet when compared to rice bran diets. This could be as a result of the higher amount of crude protein in wheat bran and the bio-availability and utilization of all the nutrients in the pelleted diet. Low growth rate in *O. niloticus* fed on rice bran have been attributed to the fact that rice bran is nutritionally inferior to wheat bran and maize bran. Rice bran may be mixed with hulls and broken rice resulting in high crude fibre content and low protein level content, which leads to poor feed efficiency and lower digestibility and utilization by the fish [18]. Digestibility of rice bran has been found to be low (41%) in Stripped bass, *Morone saxatilis* cross *Morone chrysops* and as low as (38%) in Thai Koi (*Anabas testudineus*), while fishmeal digestibility is high (80%) in the same species [19]. Therefore, reduced digestibility in CRBp and CRBup may be due to inclusion of rice bran, hence low growth performance. However, the resultant low growth of fish fed CWBup and CRBup relative to CWBp and CBP, respectively, may be attributed mainly to differences in nutrient bio-availability since the same ingredients were used. It has been reported that inclusion of *C. nilotica* as a sole source of protein promotes the growth of *O. niloticus* [20].

Feed conversion ratio (FCR) is an important indicator of quality of fish feed, a lower FCR indicating better utilization of the fish feed. Feed conversion ratio (FCR) data from catfish studies appear to depend on growth stages, feed form, and culture system used. Feed conversion rate (FCR) values for catfish fed non-conventional feeds range from 6.4 to 1.6 [21, 22] but can be lower for juveniles fed on commercial diets. In the present study, FCR ranged from 3.44 to 2.45 and are thus within acceptable levels. However, it is noteworthy that commercial diets often incorporate vitamin premixes and amino acids, which was not done in the present study. Further study, is required to determine the effect of such dietary additions to the overall performance of fish diets based on locally available feed sources.

In the present study, the growth curves were similar and undistinguishable during the first month. Well-fertilized ponds contain high protein from phytoplankton, zooplankton and invertebrates such as insects and crustaceans, which are an essential source of protein for newly stocked catfish fingerling in ponds. After the first month, the fish had grown to a mean weight of 30.2g and the utilization of the natural food was apparently reduced since the fish relied on the experimental diets administered. The present study indicates that contribution of natural organisms to growth in the larger African catfish is minimal. Natural organisms are reported to provide only 2.5% of protein and 0.8% of energy requirement of large African catfish [23]. The similarity in growth curves could be an indicator that it is possible to gain more profit by utilizing the less costly fish feed at this stage. This deserves further study.

In the present study, inorganic as opposed to organic fertilizer was used to support speed build-up of sufficient amounts of natural food before stocking. While it takes organic fertilizer about 8-10 weeks to fully break down and release nutrients, inorganic fertilizers dissolve within minutes [24]. This would make inorganic fertilizers more suitable. However, a study on effects of organic and inorganic fertilizers on Bighead carp (*Aristichthys nobilis)* [25] found better growth performance when inorganic and organic fertilizers were used in combination. The effects of using either organic, inorganic or a combination on catfish growth performance should be evaluated.

The cost benefit analysis in this present study did not take into consideration the cost of both pond construction and water as these were considered a constant. On the other hand, the cost of pelleting was applicable only to the pelleted feed. Although there were positive returns for all the diets, CWBp was the most profitable compared with the other dietary treatments. This observation is in agreement with other authors who indicated that inclusion of wheat bran in fish diets is cost-effective in the production of *O. niloticus* in fertilized ponds [26]. The cost of inorganic fertilizer can often be considerably higher than organic fertilizers. However, since only a single type of fertilizer was used among the different treatments in the present study, the cost of fertilization was constant, and the use of either type of fertilization is not expected to affect the results of cost benefit analysis. The net economic returns were also higher in the pelleted diets. The lower profits in the CRBup were as a result of the low utilization of the feed by the fish hence lower weight gain. The use of wheat bran in the fish feed formulation indicated higher returns than use of rice bran. The results of the present study have shown that pelleting fish feed ensures binding of all the required nutrients required by the fish, hence maximum utilization of the fish feed. It also agrees with other studies, which indicate that agricultural by-products can be used as effectively as commercial feeds for production of African catfish [27, 28]

CONCLUSION AND RECOMMENDATIONS

Considering the availability of the used agro-industrial by-products in the Lake Victoria basin [29] and the results from the present study, it can be concluded that pelleted *C. nilotica* and wheat bran (CWBp) diet is profitable and can be used efficiently for production of *C. gariepinus* in fertilized earthen ponds. Similarly, pelleted *C. nilotica* and rice bran (CRBp) can be utilized in regions where wheat bran is not available since it has shown better growth performance, second after CWBp. Pelleting of fish feeds leads to better nutrient utilization and growth of *C. gariepinus* and can lead to increased profits for catfish farmers regardless of the extra production cost involved.

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Table 1: Growth performance of *C. gariepinus* fed on four different diets for 5 months

Variable	Dietary Treatments*			
	CRBp	**CRBup**	**CWBp**	**CWBup**
Stocking weight (g fish $^{-1}$)	1.75±0.04[a]	1.76±0.04[a]	1.78±0.06[a]	1.72±0.06[a]
Harvest weight (g fish $^{-1}$)	224.9±3.91[a]	190.9±4.47[b]	266.8±4.21[c]	211.4±4.46[d]
Mean Gross yield (Kg)	90.0±0.04[a]	76.4±0.08[b]	106.7±0.06c	84.6±0.07d
Mean Net fish yield (Kg)	89.3±0.32[a]	75.6±0.61[b]	106.0±0.44[c]	83.9±0.51[d]
SGR (% day $^{-1}$)	3.24±0.05[a]	3.12±0.03[b]	3.34±0.06[c]	3.21±0.01[d]
FCR	2.91±0.04[a]	3.44±0.05[b]	2.45±0.05[c]	3.10±0.06[d]
Condition factor	1.34±0.02[a]	1.35±0.04[a]	1.33±0.02[a]	1.34±0.04[a]

Values are means±standard deviations. Values with the same superscripts in a row are not significantly different

**CRBp, C. nilotica and rice bran pelleted; CWBp, C. nilotica and wheat bran pelleted; CWBup, C. nilotica and wheat bran un-pelleted.*

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Table 2: Water quality parameters measured in the morning in ponds under different dietary treatments

Parameter	Dietary Treatment			
	CRBp	**CRBup**	**CWBp**	**CWBup**
pH	7.40±0.01[a]	7.41±0.01[a]	7.41±0.01[a]	7.43±0.02[a]
Dissolved oxygen (mgL^{-1}, 1000h)	2.17±0.13[a]	2.01±0.12[a]	1.78±0.11[a]	1.98±0.13[a]
Temperature (^{o}C)	23.20±0.11[a]	23.21±0.12[a]	23.22±0.11[a]	23.20±0.11[a]
Conductivity (µs)	86.53±1.34[a]	85.22±1.30[a]	84.40±1.28[a]	85.21±1.52[a]

Values are means±standard deviations. Values with the same superscripts in a row are not significantly different

**CRBp, C. nilotica and rice bran pelleted; CRBup, C. nilotica and rice bran un-pelleted; CWBp, C. nilotica and wheat bran pelleted; CWBup, C. nilotica and wheat bran un-pelleted*

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Table 3: Cost benefit analysis for the dietary treatments

Item	Unit	CRBp	CRBup	CWBp	CWBup
Gross revenue	US$	224.0± 0.60[a]	190.9±0.01 [b]	266.8±0.33 [c]	211.4±0.01 [d]
Variable cost	US$	80.8±0.83[a]	78.8±0.33 [b]	86.1±0.67 [c]	84.0±0.00 [d]
Income above variable cost	US$	143.2±0.34 [a]	112.1±0.01 [b]	180.7±0.33 [c]	127.4±0.44 [d]
Fixed costs	US$	0.63±0.00 [a]	0.63±0.00 [a]	0.63±0.00 [a]	0.63±0.00 [a]
Total costs	US$	81.5±0.37 [a]	79.4±0.00[b]	86.7±0.00 [c]	84.6±0.00 [d]
Net return	US$	142.5±0.37[a]	111.5±0.00[b]	180.1±0.00[c]	126.8±.37[d]
Break even yield (variable cost)	US$	0.54±0.00[a]	0.53±0.00[b]	0.58±0.00[c]	0.56±0.00[d]
Break even yield (total cost)	US$	0.31±0.00[a]	0.16±0.00[b]	0.48±0.00[c]	0.21±0.01[d]

Values are means±standard deviations. Values with the same superscripts in a row are not significantly different

**CRBp, C. nilotica and rice bran pelleted; CRBup, rice bran un-pelleted; CWBp, C. nilotica and wheat bran pelleted; CWBup, C. nilotica and wheat bran un-pelleted*

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