

Nutritional Characteristics of Red Lady and Sunrise Solo Papaya (*Carica Papaya L.*) Seed Powders and Their Effects on the Growth Performance of African Catfish (*Clarias Gariepinus*)

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Abstract

This study evaluated the nutritional characteristics of seed powders from Red Lady and Sunrise Solo papaya (Carica papaya L.) and assessed their effects on the growth performance of African catfish (Clarias gariepinus). Proximate composition, selected minerals, fatty acids and phytochemicals of the two papaya seed powders were determined, while growth was evaluated in a 70-day feeding trial using a completely randomized design with three dietary treatments: a control diet without papaya seed powder (T1), a diet containing 1% Sunrise Solo seed powder (T2), and a diet containing 1% Red Lady seed powder (T3), each replicated three times. Ninety fingerlings were stocked at 10 fish per 1 m³ concrete tank and fed at 5% body biomass daily. Red Lady seed powder recorded higher crude protein (27.45 ± 0.21%), ether extract (28.20 ± 0.18%), ash (8.40 ± 0.10%), calcium (0.27 ± 0.00 mg/g), magnesium (0.29 ± 0.00 mg/g), potassium (0.68 ± 0.00 mg/g), phosphorus (0.36 ± 0.00 mg/g) and iron (191.81 ± 0.05 mg/g) than Sunrise Solo, whereas Sunrise Solo had higher nitrogen-free extract and carotenoid content. Red Lady also recorded higher flavonoids, phenols, alkaloids, tannins and saponins, while both varieties had no detectable glucosinolate. The fatty-acid profile showed cultivar-specific differences, with Sunrise Solo generally higher in palmitic, oleic, linoleic and linolenic acids, whereas Red Lady had higher lauric, margaric and valeric acids. In the feeding trial, Red Lady produced the highest final weight (44.83 ± 2.89 g), weight gain (26.23 ± 4.24 g), percentage weight gain (191.17 ± 34.91%), specific growth rate (1.63 ± 0.02% day⁻¹) and condition factor (0.72 ± 0.02). Survival did not differ significantly among treatments. The findings demonstrate clear cultivar-specific nutritional differences and indicate that 1% Red Lady papaya seed powder was associated with superior growth performance of C. gariepinus under the conditions of the study.

Keywords: *Carica papaya; Red Lady; Sunrise Solo; Clarias gariepinus; papaya seed powder; proximate composition; growth performance; condition factor.*

1. Introduction

Aquaculture is increasingly important to food and nutrition security, particularly where capture fisheries cannot meet rising demand for fish. In Nigeria, African catfish (*Clarias gariepinus*) is one of the principal cultured species because of its rapid growth, hardiness and adaptability to intensive culture systems. However, feed remains one of the largest components of production

cost, creating continuing interest in locally available feed ingredients and functional additives that can improve nutrient utilization and reduce dependence on conventional inputs.

Plant-derived materials are increasingly investigated as aquafeed ingredients because they may provide protein, lipids, minerals and bioactive compounds while also contributing to agricultural-waste valorization. Papaya seeds are an underutilized by-product with appreciable protein and lipid contents and a range of phytochemicals. Previous work reported in previous studies indicates that papaya seeds contain nutritionally useful lipids and other bioactive compounds and have potential applications in fish diets (Aravind *et al.*, 2013; Akinoso & Raji, 2011; Ezinwannebo *et al.*, 2019). The nutritional value of seed material, however, can vary with cultivar, growing conditions and processing, making comparative characterization important before recommending a particular variety.

The present study focused specifically on two cultivated papaya varieties, Red Lady and Sunrise Solo. The thesis identified differences between the two seed powders in proximate composition, mineral profile, fatty-acid composition and phytochemical constituents. Such differences are potentially relevant to aquafeed performance because dietary protein and lipid supply energy and structural nutrients, minerals support metabolic and skeletal functions, and phytochemicals may modify palatability, digestion or antioxidant responses.

Papaya seed supplementation has also been investigated in fish. Studies reported in previous studies reported improved growth and feed utilization following papaya seed supplementation in cultured fish, including *C. gariepinus* (Omitoyin *et al.*, 2006; Oso *et al.*, 2019; Olopade *et al.*, 2020; Nwanna *et al.*, 2022). Nevertheless, responses can depend on inclusion level, processing, fish size, basal diet and cultivar. Comparative evidence for Red Lady and Sunrise Solo seed powders at a low 1% inclusion level in African catfish remains limited.

Therefore, this publication isolates two objectives: (i) to determine the nutritional composition of Red Lady and Sunrise Solo papaya seed powders, including proximate composition, phytochemicals, fatty acids and minerals; and (ii) to assess growth performance of *C. gariepinus* fingerlings fed diets containing the two seed powders at 1% inclusion, using a control diet for comparison.

2. Materials and Methods

2.1 Experimental site

The study was carried out at the Niger Delta University Teaching and Research Farm, Wilberforce Island, Bayelsa State, Nigeria, located at latitude 4.9784619 and longitude 6.1036914. The feeding trial lasted 70 days.

2.2 Experimental design and culture facility

A completely randomized design (CRD) was used with three dietary treatments and three replicates per treatment. Treatment T1 was the control diet without papaya seed powder; T2 contained 1% Sunrise Solo papaya seed powder; and T3 contained 1% Red Lady papaya seed powder. Nine experimental units were therefore used, with 10 *C. gariepinus* fingerlings stocked in each tank, giving a total stocking density of 90 fish. The experimental units were nine rectangular reinforced-concrete tanks of approximately 1 m³ capacity (1.0 × 1.0 × 1.0 m).

2.3 Experimental fish and acclimation

Ninety *C. gariepinus* fingerlings were obtained from the Department of Fisheries, Niger Delta University Teaching and Research Farm. The fish were transported in 50-L plastic containers

and acclimatized for one week before commencement of the feeding trial. During acclimation, fish were fed commercial Coppens 2-mm feed at 5% body weight per day in two meals. Uneaten feed and faecal materials were removed daily. At the end of acclimation, fish were weighed and randomly assigned to the experimental tanks at 10 fish per tank. Feeding was withheld for 12 h before the feeding trial.

2.4 Preparation of papaya seed powders

Ripe Red Lady and Sunrise Solo fruits were sourced from a wholesale vendor along Osiri Road, Ekeki, Yenagoa, Bayelsa State. Fruits were identified using morphological characteristics and botanical descriptions. Seeds were removed, washed, air-dried, milled into fine powder, labelled by variety and stored in a cool, dry environment until use.

2.5 Experimental diets

Three experimental diets were formulated to contain approximately 40% crude protein. Papaya seed powder was incorporated at 10 g/kg diet (1%). T1 contained 0 g/kg papaya seed powder, T2 contained 10 g/kg Sunrise Solo powder and T3 contained 10 g/kg Red Lady powder. The basal ingredient composition consisted of fishmeal (32%), soybean meal (32.9%), corn meal (21.3%), papaya seed powder (0 or 1%), vitamin/mineral premix (0.5%), methionine (0.1%), lysine (0.1%), palm oil (7%), bone meal (2%), salt (0.1%) and starch (4%). Ingredients were sieved, thoroughly mixed, pelleted through a 2-mm die, sun-dried, labelled and stored at approximately 25°C until use.

Table 1. Gross composition of experimental diets

Ingredient	T1 Control (%)	T2 Sunrise Solo (%)	T3 Red Lady (%)
Fishmeal (Oreochromis niloticus), 71.26% CP	32.0	32.0	32.0
Soybean meal, 45.25% CP	32.9	32.9	32.9
Corn meal, 10.85% CP	21.3	21.3	21.3
Papaya seed powder	0	1.0	1.0
Vitamin/mineral premix	0.5	0.5	0.5
Methionine	0.1	0.1	0.1
Lysine	0.1	0.1	0.1
Palm oil	7.0	7.0	7.0
Bone meal	2.0	2.0	2.0
Salt	0.1	0.1	0.1
Starch	4.0	4.0	4.0
Total	100.0	100.0	100.0

2.6 Feeding and water-quality management

Fish were fed the experimental diets at 5% of total biomass per day, divided into two feeding periods. The daily ration was adjusted weekly following biomass measurements. Uneaten feed and tank wastes were removed daily, and freshwater was replenished as required. Water was

flushed twice weekly. Temperature was monitored daily at 08:00 h using a mercury-in-glass thermometer, while dissolved oxygen and pH were monitored using water-quality kits. The same husbandry procedures were applied across all treatments.

2.7 Proximate composition

Proximate composition of the papaya seed powders was determined using AOAC procedures (AOAC, 2000). Moisture was determined by oven drying at 105°C to constant weight; crude protein by Kjeldahl analysis using a nitrogen-to-protein conversion factor of 6.25; crude fat by Soxhlet extraction with petroleum ether; crude fibre by sequential acid and alkali digestion followed by drying and ashing; total ash by furnace ashing at 550°C; and nitrogen-free extract (NFE) by difference.

2.8 Mineral composition

Approximately 1 g of each finely ground seed sample was digested using concentrated nitric and hydrochloric acids. Calcium, magnesium, potassium and iron were determined by atomic absorption spectroscopy, while phosphorus was determined colorimetrically using the molybdenum-blue method, following the procedures stated in the thesis (AOAC, 2005; Murphy & Riley, 1962).

2.9 Fatty-acid and phytochemical analyses

Fatty-acid composition was determined for each papaya seed powder and reported as the percentage contribution of the individual fatty acids detected. The fatty acids evaluated were lauric, stearic, palmitic, arachidonic, oleic, margaric, linoleic, ligoleic, myristic, behenic, butyric, valeric, palmitoleic, caprylic, propionic and linolenic acids. Phytochemical analysis was conducted on the two seed powders, and the concentrations of flavonoids, phenols, alkaloids, tannins, saponins, carotenoids and glucosinolates were determined and expressed as mg/100 g.

2.10 Growth measurements

Fish were weighed weekly using a digital electronic balance with 0.01-g sensitivity after gently blotting excess water from each fish. Total length was measured using a calibrated ruler. Weight gain (WG) was calculated as final weight minus initial weight; percentage weight gain (PWG) as $[(\text{final weight} - \text{initial weight})/\text{initial weight}] \times 100$; condition factor (K) as $W/L^3 \times 100$, where W is body weight and L is total length; and specific growth rate (SGR) as $100[\ln(\text{final weight}) - \ln(\text{initial weight})]/\text{trial duration}$. Survival was calculated as the number of fish alive at the end of the experiment relative to the initial number of fish, expressed as a percentage.

2.11 Statistical analysis

Data were analysed using one-way analysis of variance (ANOVA). Where significant treatment effects were detected, means were separated using Duncan's Multiple Range Test at $p \leq 0.05$. Statistical analyses were performed using Microsoft Excel and SPSS. Results are presented as mean $\pm$ standard deviation (SD). Within a row, means carrying different superscript letters differ significantly at $p \leq 0.05$.

3. Results

3.1 Proximate composition

The two papaya seed powders had broadly similar proximate profiles, but significant cultivar differences occurred in moisture, crude protein, crude fibre, ash and NFE. Red Lady recorded higher crude protein, ether extract, crude fibre and ash, whereas Sunrise Solo had higher NFE. Moisture did not differ significantly.

Table 2. Proximate composition of Sunrise Solo and Red Lady papaya seed powders

Parameter	Sunrise Solo	Red Lady
Moisture (%)	7.92 ± 0.15a	7.85 ± 0.14a
Crude protein (%)	26.80 ± 0.20b	27.45 ± 0.21a
Ether extract (%)	27.65 ± 0.17a	28.20 ± 0.18a
Crude fibre (%)	14.85 ± 0.11b	15.10 ± 0.12a
Ash (%)	8.15 ± 0.09b	8.40 ± 0.10a
NFE (%)	14.63 ± 0.18b	13.00 ± 0.16a

Note: Values are mean ± SD (n = 3). Different superscript letters across rows indicate significant difference at $p \leq 0.05$.

3.2 Mineral composition

Table 3. Mineral composition of Sunrise Solo and Red Lady papaya seed powders

Mineral	Sunrise Solo (mg/g)	Red Lady (mg/g)
Ca (mg/g)	0.26 ± 0.00b	0.27 ± 0.00a
Mg (mg/g)	0.27 ± 0.00b	0.29 ± 0.00a
K (mg/g)	0.47 ± 0.00b	0.68 ± 0.00a
P (mg/g)	0.32 ± 0.00b	0.36 ± 0.00a
Fe (mg/g)	174.30 ± 0.00b	191.81 ± 0.05a

Red Lady recorded significantly higher Ca, Mg, K, P and Fe concentrations than Sunrise Solo.

3.3 Fatty-acid composition

Table 4. Fatty-acid composition of Sunrise Solo and Red Lady papaya seed powders

Fatty acid	Sunrise Solo (%)	Red Lady (%)
Lauric	1.01 ± 0.00	1.08 ± 0.00
Stearic	1.23 ± 0.00	1.15 ± 0.00
Palmitic	1.54 ± 0.01	1.36 ± 0.00
Arachidonic	1.02 ± 0.00	1.00 ± 0.00
Oleic	2.00 ± 0.00	1.92 ± 0.00
Margaric	0.72 ± 0.00	0.73 ± 0.01
Linoleic	1.02 ± 0.01	1.00 ± 0.00
Ligoleric	0.82 ± 0.01	0.78 ± 0.00
Myristic	0.76 ± 0.00	0.68 ± 0.01
Behenic	1.06 ± 0.01	1.03 ± 0.00
Butyric	0.16 ± 0.00	0.13 ± 0.00
Valeric	0.37 ± 0.00	0.45 ± 0.00
Palmitoleic	0.92 ± 0.00	0.88 ± 0.00
Caprylic	0.43 ± 0.00	0.40 ± 0.01
Propionic	0.31 ± 0.00	0.27 ± 0.00

Linolenic	0.61 ± 0.00	0.56 ± 0.00
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Sunrise Solo generally recorded higher palmitic, oleic, linoleic and linolenic acids, whereas Red Lady recorded higher lauric, margaric and valeric acids. The thesis reports significant differences among the fatty acids.

3.4 Phytochemical composition

Table 5. Phytochemical composition of Sunrise Solo and Red Lady papaya seed powders

Phytochemical	Sunrise Solo	Red Lady
Flavonoid (mg/100 g)	4.25 ± 0.02b	6.20 ± 0.03a
Phenol (mg/100 g)	92.34 ± 0.04b	99.24 ± 0.22a
Alkaloid (mg/100 g)	10.89 ± 0.03b	12.14 ± 0.02a
Tannin (mg/100 g)	88.18 ± 0.03b	92.58 ± 0.04a
Saponin (mg/100 g)	24.84 ± 0.02b	26.60 ± 0.02a
Carotenoid (mg/100 g)	5.27 ± 0.03b	3.49 ± 0.01a
Glucosinolate (mg/100 g)	0.00	0.00

Red Lady had higher flavonoid, phenol, alkaloid, tannin and saponin concentrations, whereas Sunrise Solo had higher carotenoid concentration. No detectable glucosinolate was reported for either variety.

3.5 Growth performance of *Clarias gariepinus*

Table 6. Growth performance of *Clarias gariepinus* fingerlings fed experimental diets

Parameter	Control	Sunrise Solo	Red Lady
Initial length (cm)	14.02 ± 0.23a	13.75 ± 0.24a	13.84 ± 0.34a
Initial weight (g)	19.90 ± 0.60a	18.53 ± 0.71a	18.60 ± 1.40a
Final length (cm)	16.65 ± 0.25a	16.73 ± 0.92a	18.30 ± 0.30a
Final weight (g)	23.25 ± 0.78b	32.66 ± 6.33ab	44.83 ± 2.89a
Length increase (cm)	2.60 ± 0.48a	2.98 ± 1.01a	4.45 ± 0.58a
Weight gain (g)	3.35 ± 0.15b	14.13 ± 6.20ab	26.23 ± 4.24a
Weight gain (%)	23.87 ± 0.66b	102.65 ± 45.35ab	191.17 ± 34.91a
SGR (%/day)	1.33 ± 0.01b	1.46 ± 0.10ab	1.63 ± 0.02a
Condition factor (K)	0.65 ± 0.03b	0.67 ± 0.07ab	0.72 ± 0.02a
Survival (%)	55.00 ± 5.00a	53.33 ± 3.33a	53.33 ± 3.33a

Red Lady produced the highest final weight, weight gain, percentage weight gain, SGR and condition factor. Initial length and weight did not differ significantly among treatments. Survival also did not differ significantly.

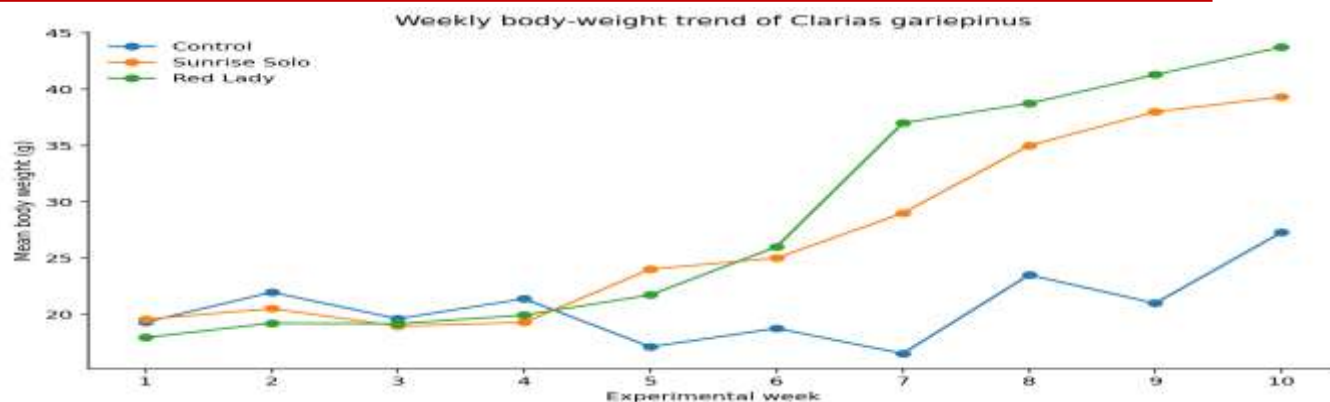


Figure 1. Weekly mean body-weight trend of *Clarias gariepinus* during the 10-week feeding trial.

4. Discussion

4.1 Nutritional characteristics of papaya seed powders

The proximate composition demonstrated that both cultivars contain appreciable protein and lipid fractions, with Red Lady having slightly higher crude protein (27.45%) and ether extract (28.20%) than Sunrise Solo (26.80% and 27.65%, respectively). The protein values fall within the broad range reported for papaya seeds in the study literature. Eke *et al.* (2010) reported nutritional constituents for *C. papaya* seeds, while Akinoso and Raji (2011) characterized papaya seed flour and documented its usefulness as a nutrient-rich plant material. The present values also agree with the study discussion citing Aravind *et al.* (2013), which identified papaya seeds as a lipid-rich plant material. The relatively high lipid concentration is nutritionally relevant because lipids can provide dietary energy and thereby spare protein for tissue deposition.

Crude fibre was 14.85% in Sunrise Solo and 15.10% in Red Lady. The values are close to the moderate fibre levels reported by Akinoso and Raji (2011). Fibre is useful at appropriate levels, but excessive fibre can reduce nutrient digestibility and limit inclusion in formulated feeds. This provides a rationale for the low 1% inclusion used in the feeding trial rather than treating papaya seed powder as a complete replacement for conventional protein ingredients.

Red Lady showed higher mineral concentrations for all five minerals measured. Particularly notable were potassium (0.68 mg/g versus 0.47 mg/g), phosphorus (0.36 versus 0.32 mg/g) and iron (191.81 versus 174.30 mg/g). This cultivar effect is consistent with the thesis citation to Akinola *et al.* (2016), who examined mineral profiles of papaya seeds from different sources. Variation among cultivars can reflect genetic differences and environmental conditions affecting mineral uptake. In practical aquafeed formulation, these mineral differences are potentially relevant because phosphorus is associated with skeletal development and energy metabolism, while iron is important in oxygen transport.

The fatty-acid results further demonstrate that the two cultivars should not be treated as nutritionally identical. Sunrise Solo had higher oleic, linoleic and linolenic acids, while Red Lady had higher lauric and valeric acids. The thesis compared these findings with literature describing papaya seeds as lipid-rich and with a substantial unsaturated fatty-acid fraction (Aravind *et al.*, 2013; Akinola *et al.*, 2016). Lipid composition can affect the energy supplied by a diet and the fatty-acid environment available for fish metabolism. However, because the present study measured fatty acids in the seed powders rather than in the formulated diets or fish tissues, the results should be interpreted as ingredient characterization rather than proof of direct tissue-level fatty-acid effects.

Phytochemical analysis showed higher flavonoid, phenol, alkaloid, tannin and saponin levels in Red Lady, while Sunrise Solo had more carotenoids. Both varieties showed no detectable glucosinolate. Papaya seed bioactive compounds have been discussed as potential contributors to antioxidant and antimicrobial functions (Aravind *et al.*, 2013; Awoyemi *et al.*, 2019). At the same time, tannins and saponins can act as antinutritional factors when present at sufficiently high levels. Francis *et al.* (2001) emphasized that plant-derived antinutritional factors can influence nutrient utilization in fish diets. The absence of detectable glucosinolate in the present seed samples is therefore a useful observation, but it does not mean that all antinutritional effects are absent.

4.2 Growth performance

The most important growth response was the markedly greater final weight and weight gain of fish fed the Red Lady diet. Final weight increased from 18.60 g initially to 44.83 g, producing a weight gain of 26.23 g and percentage weight gain of 191.17%. Sunrise Solo produced an intermediate response, while the control had the lowest final weight and gain. SGR followed the same ranking, with 1.63% day⁻¹ in Red Lady, 1.46% day⁻¹ in Sunrise Solo and 1.33% day⁻¹ in the control. These results support the thesis conclusion that cultivar-specific papaya seed supplementation was associated with improved growth.

The direction of the present findings agrees with earlier work reported in previous studies. Omitoyin *et al.* (2006) reported growth-promoting potential of pawpaw seed meal in African catfish, while Oso *et al.* (2019) reported growth and nutrient-utilization responses in *C. gariepinus* fed papaya seed powder. Olopade *et al.* (2020) likewise investigated papaya seed supplementation in *C. gariepinus* and reported effects on growth and health. The present study extends this body of evidence by comparing two papaya cultivars at a relatively low 1% inclusion level rather than evaluating only one generic papaya seed source.

The superior performance of Red Lady may be associated with its slightly higher crude protein and lipid content, as well as its higher concentrations of selected minerals and phytochemicals. The explanation should nevertheless remain cautious: the study did not directly measure digestibility, digestive enzymes, gut microbiota or nutrient retention. Consequently, the observed association between the chemical characteristics of Red Lady seed powder and improved growth cannot by itself establish a causal biochemical pathway. Similar caution is appropriate when interpreting the study discussion that attributes growth to individual phytochemicals.

Condition factor was also highest in the Red Lady group (0.72), followed by Sunrise Solo (0.67), with the control at 0.65. Condition factor is widely used as an indicator of relative body robustness and nutritional status; the thesis cites Francis *et al.* (2018) and Pandey *et al.* (2021) in this context. The higher K value in Red Lady is consistent with its higher weight gain and suggests that the treatment produced greater body mass relative to length.

Survival did not differ significantly among treatments, indicating that the superior growth of Red Lady was not accompanied by a statistically detectable survival advantage. The thesis reports final survival of approximately 55% in the control and 53.33% in each papaya-supplemented group. Because survival declined progressively during the trial, the result also highlights the importance of considering husbandry and handling conditions in addition to diet when interpreting growth experiments.

4.3 Comparison with previous studies and significance of cultivar selection

The present results are broadly consistent with the literature reported in previous studies indicating that papaya seed materials can function as dietary supplements for fish. However, the magnitude of response varies among studies because of differences in fish species, fish size, basal diet, inclusion level, processing and seed source. Ezinwannebo *et al.* (2019) and Olopade *et al.* (2020) provide examples of papaya seed supplementation in fish diets, while Nwanna *et al.* (2022) reported growth and health responses in African catfish fed diets supplemented with papaya seed meal. These comparisons support the general potential of papaya seed products but also reinforce the importance of reporting cultivar and processing conditions.

A further implication is that 'papaya seed meal' should not automatically be treated as a chemically uniform ingredient. In the present study, Red Lady and Sunrise Solo differed significantly in several proximate, mineral, fatty-acid and phytochemical characteristics. The better growth response obtained with Red Lady therefore provides preliminary evidence that cultivar selection may matter when developing plant-based functional additives for African catfish diets. This conclusion is more defensible than attributing the response to a single compound, because several chemical characteristics differed simultaneously.

Overall, the findings support the use of papaya seed powder as a low-level functional dietary additive rather than as a direct one-for-one replacement for major protein ingredients. The relatively high fibre fraction and the presence of tannins and saponins warrant controlled inclusion and proper processing. This interpretation is consistent with the wider aquaculture feed literature reported in previous studies concerning the benefits and limitations of plant-derived feed ingredients (Francis *et al.*, 2001; Orose *et al.*, 2021).

5. Conclusion

Red Lady and Sunrise Solo papaya seed powders differed significantly in several nutritional characteristics. Red Lady contained slightly more crude protein and ether extract and higher concentrations of the measured minerals and most of the quantified phytochemicals, whereas Sunrise Solo contained more NFE, carotenoids and several of the reported fatty acids. Both varieties had no detectable glucosinolate in the analysis reported by the thesis.

At 1% dietary inclusion, Red Lady papaya seed powder produced the highest final weight, weight gain, percentage weight gain, specific growth rate and condition factor in *C. gariepinus*, while survival was not significantly different among treatments. The results indicate that Red Lady seed powder has potential as a low-level functional feed additive for African catfish. However, the numerical FCR results were not reported in the thesis and should not be reconstructed without the original feed-intake data.

6. Recommendations

- Further feeding trials should compare Red Lady and Sunrise Solo at several inclusion levels to establish the optimum dietary level.
- Future studies should determine nutrient digestibility, digestive-enzyme activity and intestinal responses to clarify the mechanisms underlying the growth advantage observed with Red Lady.
- Processing methods should be standardized and antinutritional factors should be quantified before recommending large-scale inclusion.
- Because cultivar differences were evident, papaya seed source and cultivar should be stated explicitly in future aquafeed studies.

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