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Hovinu Sothu
M.Sc. Student, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland, India

M Catherine Rutsa
Associate Professor, Department of LPM, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland, India

R Zuyie
Associate Professor, Department of LPM, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland, India

VK Vidyarthi
Professor, Department of LPM, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland, India

Nizamuddin
Professor, Department of LPM, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland, India

N Savino
Associate Professor, Department of LPM, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland, India

Rajan Singh
Ph.D. Scholar, Department of LPM, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland, India

Corresponding Author:
Hovinu Sothu
M.Sc Student, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland, India

Effect of roselle (*Hibiscus sabdariffa*) calyx on the performance of *Tenyivo* pig

Hovinu Sothu, M Catherine Rutsa, R Zuyie, VK Vidyarthi, Nizamuddin, N Savino and Rajan Singh

Abstract
The present research work entitled "Effect of Roselle (*Hibiscus sabdariffa*) calyx on the performance of *Tenyivo* pig" was carried out with an aim to find out the effect of Roselle (*Hibiscus sabdariffa*) calyx on the performance of *Tenyivo* pig in terms of body weight, body weight gain, feed intake, feed conversion efficiency, morbidity, mortality and economics of pig production. Twenty weaned *Tenyivo* piglets of two to three months old was selected and divided into four treatment groups namely T_1, T_2, T_3 and T_4 consisting of five animals in each treatment. Treatment group marked as T_1 served as control group and treatment groups T_2, T_3 and T_4 were given conventional feed supplemented with Roselle (*Hibiscus sabdariffa)* calyx powder at different levels of 0.5%, 1% and 1.5%, respectively. The period of the experiment was for two months. It was observed that treatment group T_4 given 1.5% of Roselle calyx powershowed higher (p<0.05) final body weight followed by treatment group T_1, T_3 and T_2. Higher gain in weight, feed intake and better overall feed conversion efficiency with a value of 3.67 in treatment T_4 group. There was ten percent morbidity and five percent mortality during the experimental period. The maximum profit per piglet as well as per kg live weight was observed in T_4 followed by T_1, T_3 and T_2. Higher benefit cost ratio (B.C.R) of 1.25 in T_4 group was noted. Based on the results of the present study, inclusion of Roselle (*Hibiscus sabdariffa*) at 1.5% calyx powder in pig feed can be recommended.

Keywords: *Tenyi Vo* pig, Roselle calyx, Body weight, Feed intake, Feed conversion efficiency

Introduction
Livestock is an important component in Indian agriculture in terms of drought animals, for crop cultivation and transportation. Livestock in India contributes almost half of organic manure produced annually, a major attribute in crop productivity. The larger part of the rural population in the country is wedded to livestock to meet needs like food, cash or nutrition and is paving the way out of poverty for many families. India has a livestock population of 536.76 million as per the 20th livestock census contributing about 6.17% to total Gross Value Added (GVA) and 30.87% to agriculture and allied sector GVA (BAHS, 2021) [6] where about 20.5 million people depend on livestock for their livelihood, all of which depicts the importance of livestock sector in India.

In terms of food and nutritional security, occupation, poverty alleviation and sustainable income, livestock plays a crucial role in tending to these requirements of the growing population. Amongst the livestock species, pigs serve as one of the important animals in income generation for the rural population with high returns on low investment. The country has a pig population of about 9.06 million according to the 20th livestock census, contributing 1.7% to the total livestock population (DAHD, 2019) [12].

Pigs are non-ruminant animals belonging to the family Suidae of the order Artiodactyls. The ancestors of most modern breeds of swine are the European wild boar (Epstein, 1971) [13]. Domestication of swine has been known to man since the dawn of civilization. It can be dated back as early as 4900 BC in China and 1500 BC in Europe (Moeller *et al.*, 2003) [29]. Attributing mostly to the superiority of meat yield and feed conversion efficiency over other livestock and unparallel versatility and adaptability to diverse environmental conditions, pigs play an important role in the production of food for human consumption.

In India, the highest population of pig is owned by Assam of the North-East region (NER)

with 2.10 million (DAHD, 2019) [12]. About 46.8% of the total pig population in India belongs to the NER and the larger part of the NER population is fully or partially dependent on the livestock sector, especially pig farming for sustainability. The major benefit of rearing pigs as compared to rearing other livestock animals is the low cost of inputs. Another advantage of rearing pigs is that pigs can be reared with household or kitchen wastes, locally available forages or crop by products. This is a good source of income generation as it can bring about a good amount of profit with minimal expenditure with regard to feed cost.

The people of Northeast India are mostly non vegetarian and the ethnic and tribal people of North East Hill (NEH) of India are confined to their traditional food habits with meat as an integral part of the culture (Kadirvel *et al.*, 2018) [18]. Amongst the meat available in the region, there is higher demand for pork which highlights the potential and importance of pig rearing in the NER. In Nagaland, pig accounts for about 72% of the total livestock in the state and per capita consumption of pork was 7.97 kg/year in 2018-2019 which is much higher than the national average of 0.28 kg (Singh *et al*., 2021) [36]. Pork is preferred over other meat as a source of animal protein, alongside being nutritious with high fat, low water content and better energy value than that of other meats (Singh *et al*., 2020) [35]. The total production of meat in Nagaland in 2020-2021 was reported as 23.870 tonnes, out of which pork contributed 12.540 tonnes (BAHS, 2021) [6].

The people of Nagaland have a preference of meat which is locally reared and so, meat of *Tenyivo* pig is sought after. *Tenyivo* is one of the indigenous pig breeds of India belonging to Nagaland state, recognized in the year 2016 with the accession number INDIA_PIG_1400_TENYIVO_09004 (Kath *et al.*, 2019) [19] by the National Bureau of Animal Genetics Resource (NBAGR), Karnal, Haryana. *Tenyivo* pig has a strong and long tapering snout and has small erect ears. They are potbellied with black and hairy body coat and often have white markings on the forehead, flank and legs with a long tail which ends with a white switch (Rutsa & Rutsa., 2016) [33]. *Tenyivo* pigs are known to reach sexual maturity as early as three months old and are known to possess good mothering ability. The meat of *Tenyivo* is popular and well-liked among the people of Nagaland for its distinctive flavour and taste.

Roselle plants are popular in Nagaland and around the world due to their beneficial properties. Roselle (*Hibiscus sabdariffa*) plant is an annual or perennial woody based sub-shrub of height 2-2.5 m (Islam, 2019) [17] which belongs to the family malvaceae. It is locally used as herbal beverage, in the food industry as a flavouring agent and as herbal medication (Amer *et al.*, 2022) [1]. In Nagaland, it is grown as fences in the backyard garden or paddy fields and is abundantly available. The tribal people of Nagaland state often use Roselle calyx in making tea or delicious tangy curry and is grown in plenty. The surplus of Roselle calyx is fed to the pigs as feed additives for the pigs alongside paddy grains, rice polish, wheat bran and kitchen wastes. Taking into account, the availability of Roselle plants in Nagaland and its usage as folk medicines and feed additives, an experimental study was undertaken to test the effects of Roselle calyx on *Tenyivo* pig.

Method and Materials

The twenty (20) experimental piglets were divided into four treatments T_1, T_2, T_3 and T_4 consisting of five weaned piglets in each treatment and was marked as A1, A2, A3, A4, A5; B1, B2, B3, B4, B5; C1, C2, C3, C4, C5 and D1, D2, D3, D4, D5, respectively. Treatment one marked as T_1 served as control group, the other three treatments T_2, T_3 and T_4 were given conventional feed supplemented with Roselle (*Hibiscus sabdariffa)* calyx powder at different levels of 0.5%, 1% and 1.5%, respectively. The distribution of the experimental piglets and their treatments are as given in Table 1. Clean drinking water was provided *ad libitum* to the experimental animals and concentrate ration feed was given twice a day, once at 7:30 a.m. in the morning and at 4:30 p.m. in the evening.

Table 1: Chemical composition of Roselle calyx (Mohamed *et al.* 2012)

Sl. No.	Components	Percentage (%)
1.	Moisture	11.00
2.	Crude Protein	7.88
3.	Crude fibre	13.20
4.	Crude fat	0.16
5.	Ash	10.16
6.	Total carbohydrates	57.16
7.	Ascorbic acid (mg/100g)	11.00
8.	Titrable acidity (mg/100g)	9.00
9.	Total soluble solids	5.00
10.	Calcium(mg/100g)	60.00
11.	Iron (mg/100g)	25.00

A total of twenty (20) weaned *Tenyi Vo* piglets of two to three months old were randomly selected irrespective of sex from the farm of Indian Council of Agricultural Research-All India Coordinated Research on Pig (ICAR-AICRP on pig), Department of Livestock Production and Management, School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus-797106, Nagaland. Each of the experimental animals selected were ear tagged with a plastic ear tag engraved with numbers for proper identification. The identified piglets were distributed and housed in four pens comprising of five piglets in each pen irrespective of sex. The initial body weights of all the experimental animals were recorded. The animals were reared under standard housing and management system for a period of two months from 23rd August to 25th October 2022. All the experimental animals were dewormed orally with fenbendazole @ 5mg /kg body weight per animal per day for three consecutive days (Photo plate 2-B). All the experimental piglets were fed twice daily with standard conventional ration containing 20% Crude Protein per Bhat *et al.* (2010) [9]. The feed ingredients consist of grounded maize, groundnut cakes, molasses/sugar, wheat bran, fish meal and mineral mixture which were procured from the authorized dealer Animal Feeds and Needs, Medziphema, Chümukedima. The concentrated ration was freshly prepared manually in the farm feed go-down once a week. The composition of ration with 20% CP as per Bhat *et al.* (2010) [9] is presented in the Table 2.

Table 2: Composition of ration with 20% CP (Bhat *et al.* 2010) [9]

Sl. No.	Ingredients	Quantity (Kg)
1.	Maize	65
2.	Groundnut cake	14
3.	Molasses/sugar	5
4.	Wheat bran	10
5.	Fish meal	5
6.	Mineral mixture	1
	Total	100

The experimental animals were housed under standard housing system with cemented floors, brick walls and corrugated galvanized iron roofing. The pens were thoroughly washed, cleaned and disinfected using 0.5% potassium permanganate ($KmnO_4$) and left to dry for two days before the experimental piglets were introduced into the pens. A footbath was prepared at the entrance of the piggery shed containing 0.5% potassium permanganate ($KmnO_4$) solution for the purpose of disinfection which was replaced daily every morning with freshly prepared $KmnO_4$ solution. Prior to each feeding and watering of the animals, the four pens along with the feeding and watering troughs were thoroughly cleaned twice daily morning and evening. The individual body weight was recorded at the commencement of the experimental work and thereafter, individual body weight was recorded on a weekly basis till the completion of the study.

The quantity/amount of ration fed to the piglets was recorded and the left-over feed residue, if any, was collected and weighed. Feed intake was calculated by subtracting the left-over feed from the total amount of feed given to the piglets. The experimental animals were observed daily to assess the health status and wellbeing of the animals. The normal activities such as animal's movement, alertness, feed and water intake, defecation and urination, nasal and eye discharges were observed throughout the experimental period. The economics of pig production was calculated on the overall cost of inputs: the cost of piglets, cost of feed, labour charges, electricity, medicines, water and other miscellaneous cost. To obtain the total cost of feed, the total quantity of feed consumed during the experimental period and the feed cost per kilogram was taken into account. The final live weight of the piglet at the end of the experiment was considered for calculating the gross return per piglet and net profit per piglet. The experimental data collected were statistically analysed using Completely Randomized Design (CRD) as prescribed by Snedecor and Cochran (1994) [38]. One-way analysis of variance (ANOVA) was used to analyse difference between the treatments at 5% level of significance. The differences between the treatment means were analysed using Duncan's multiple range test (DMRT) method.

Result and Discussion

The pattern of average body weights in different treatment group up to the ninth week is given in Table 4. The average body weights at the initial period were recorded as 3.69 kg, 3.67 kg, 3.61 kg and 3.91 kg for T_1, T_2, T_3 and T_4, respectively. The average body weight in the first and second week were recorded as 3.89 kg, 3.85 kg, 3.79 kg, 4.11 kg and 4.12 kg, 4.05 kg, 4.03 kg, 4.33 kg for T_1, T_2, T_3 and T_4, respectively with no significant difference (p>0.05). During the fourth and fifth week of the experimental period, the average body weight recorded was numerically higher in treatment group T_4 and was recorded as 5.03 kg and 5.39 kg however, statistical analysis showed no significant difference as compared to other treatment groups.

Table 3: Effect of Roselle calyx powder on the body weight of *Tenyi Vo* pig

	Body weight (kg)									
Week	**Initial**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**
T_1	3.69[a]	3.89[a]	4.12[a]	4.44[a]	4.71[a]	5.04[a]	5.35[ab]	5.88[b]	6.29[b]	6.73[b]
T_2	3.67[a]	3.85[a]	4.05[a]	4.27[a]	4.51[a]	4.79[a]	5.08[b]	5.44[b]	5.76[b]	6.13[b]
T_3	3.61[a]	3.79[a]	4.03[a]	4.26[a]	4.56[a]	4.83[a]	5.15[b]	5.47[b]	5.84[b]	6.26[b]
T_4	3.91[a]	4.11[a]	4.33[a]	4.60[a]	5.03[a]	5.39[a]	5.87[a]	6.43[a]	6.90[a]	7.59[a]
Sem±	0.15	0.15	0.15	0.15	0.15	0.17	0.19	0.17	0.18	0.19
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.56	0.52	0.56	0.58

Note: NS = Non-significant at 5%

[a, b, c] Means bearing different superscripts in a column differ significantly.

Significant difference (p<0.05) was recorded in the sixth, seventh, eighth and ninth week of the experimental period and the recorded average body weight were 5.35 kg, 5.08 kg, 5.15 kg, 5.87 kg; 5.88 kg, 5.44 kg, 5.47 kg, 6.43 kg; 6.29 kg, 5.76 kg, 5.84 kg, 6.90 kg and 6.73 kg, 6.13 kg, 6.26 kg, 7.59 kg for T_1, T_2, T_3 and T_4, respectively. In the sixth week, the statistical data analysis indicated that T_4 differed significantly (p<0.05) from T_2 and T_3. The difference between group of T_1, T_2, and T_3 group was non-significant in the seventh, eighth and ninth week, however, T_4group which was given 1.5% Roselle calyx powder was significantly different (p<0.05) with the other treatment groups. From the perusal of data, it was observed that T_4 showed higher final body weight followed by$T_1$and treatment group T_3 and T_2 which is in agreement with the findings of Amer *et al.* (2023) [2] who reported higher final body weight in pigs fed a diet supplemented with nutgall (*Rhus semialata*). Similarly, Lei *et al.* (2018) [24] also reported greater final body weight in pigs given a diet supplemented with natural and fermented herbs than those fed with control diet. However, Zhou *et al.* (2013) [40] found no significant effect of *Coptis Chinenis* on the body weight of growing-finishing pigs. Also, Oanh *et al.* (2021) [31] reported no significant effect of medicinal plant mixture on the final body weight of growing pigs. The differences in the findings may be due to the genetic makeup, inter breed variation, environmental effect and management practices over and above the difference in the test material.

Body Weight Gain

The pattern of growth and average weekly body weight gain in different treatment group up to the ninth week is given in Table 4. The average body weight gain in the first and second week were recorded as 0.21 kg, 0.18 kg, 0.19 kg, 0.20 kg and 0.23 kg, 0.20 kg, 0.24 kg, 0.22 kg/pig/week in T_1, T_2, T_3 and T_4, respectively and differences in the treatment group were non-significant (P>0.05).In the third week of the experimental period, the average gain in body weight were recorded as 0.32 kg, 0.22 kg, 0.23 kg and 0.27 kg for T_1, T_2, T_3 and T_4, respectively with T_1 differing significantly with treatment group T_2 andT_3. The corresponding average body weight gain in the fourth week was 0.27 kg, 0.24 kg, 0.30 kg and 0.44 kg with T_4 significantly higher (p<0.05) than other treatment group. During the fifth week, T_4 was numerically higher as compared to other groups but no significant difference was observed. In the sixth, seventh, eighth and ninth, the statistical data analysis showed significant difference (p<0.05) amongst the treatment group and the average body weight gain were recorded as 0.31 kg, 0.29 kg, 0.33 kg, 0.48 kg;0.40 kg, 0.36

kg, 0.31 kg, 0.55 kg; 0.41 kg, 0.32 kg, 0.38 kg, 0.47 kg and 0.44 kg, 0.37kg, 0.42 kg, 0.65 kg for T_1, T_2, T_3 and T_4, respectively.T_4 group recorded higher (p<0.05) gain in body weight from sixth to ninth week.

Table 4: Effect of Roselle calyx powder on the weekly body weight gain of *Tenyi Vo* pig

Weekly Body weight gain (kg)									
Treatment	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**
T_1	0.21^a	0.23^a	0.32^a	0.27^b	0.33^a	0.31^b	0.40^b	0.41^c	0.44^b
T_2	0.18^a	0.20^a	0.22^b	0.24^b	0.28^a	0.29^b	0.36^{bc}	0.32^b	0.37^b
T_3	0.19^a	0.24^a	0.23^b	0.30^b	0.27^a	0.33^b	0.31^c	0.38^{bc}	0.42^b
T_4	0.20^a	0.22^a	0.27^{ab}	0.44^a	0.36^a	0.48^a	0.55^a	0.47^a	0.65^a
SEm±	0.01	0.02	0.02	0.03	0.03	0.04	0.02	0.03	0.02
CD (P=0.05)	NS	NS	0.06	0.08	NS	0.13	0.07	0.08	0.07

Note: NS = Non-significant at 5%

[a, b, c] Means bearing different superscripts in a column differ significantly.

Similar finding was reported by Park *et al*. (2000) [32], who recorded a higher average daily gain in weaned pigs fed a diet supplemented with herbs mixture. In agreement with the current findings, Lei *et al.* (2018) [24] also reported greater average daily gain in growing-finishing pigs given dietary supplementation of natural and ferment herbs as compared to control group. Amer *et al.* (2023) [2] observed higher body weight in weaned pigs supplemented with nutgall (*Rhus samialata)* which corresponds with the current finding. In contrary, Aphirakchatsakun *et al*. (2008) [4] found no significant effect in crossbred post-weaned pigs given dietary supplementation of Roselle (*Hibiscus sabdariffa*) calyx. The differences could be due to the variation in the level (4%, 8%, and 12%) of inclusion of the test materials as compared to the present level of inclusion *i.e*. 0.5%, 1% and 1.5%. Therefore, based on the present experimental finding, Roselle calyx up to 1.5% can be recommended for inclusion in diet to get better body weight gain.

Feed Intake

The pattern of weekly average feed intake of different experimental groups from the initial week up to the ninth week is presented the statistical analysis on the weekly average feed intake up to the ninth week is presented in table 5. The total feed intake for the entire experimental period recorded was 11.22 kg, 10.53 kg, 10.68 kg and 12.87 kg/pig for T_1, T_2, T_3 and T_4, respectively. In the first week, the average consumption of feed was 0.83 kg, 0.80 kg, 0.83 kg and 0.86 kg/pig/week for T_1, T_2, T_3andT_4, respectively. In the first three weeks, the analysis revealed that the difference among the treatment groups were non-significant (P>0.05). The corresponding feed intake of the animals on the fourth week of the experimental work was 1.17 kg, 1.07 kg, 1.05 kg and 1.26 kg, respectively in which no significant difference was noted between T_4 and T_1 but T_4 group differed significantly with T_2 and T_3. Similar feed intake pattern was recorded in the fifth week. In the sixth week, higher feed intake was observed in treatment groups T_2 and $T_4$with no significant difference between the two treatment groups but T_1 and T_3 differed significantly (p<0.05) with T_4. The feed intake recorded for T_4 was 1.60 kg, 1.88 kg and 2.31kg in the seventh, eighth and ninth week, respectively which was significantly higher (p<0.05) than other treatment groups followed by T_1, T_3 and T_2. Higher feed intake in T_4 may be because of the increased palatability of feed due to higher inclusion of Roselle calyx powder. The result was in accordance with the findings of Park *et al.* (2000) [32] who also reported greater average daily feed intake in growing-finishing's pigs treated with dietary supplementation of herb mixture. Similarly, Amer *et al.* (2023) [2] also reported higher feed intake in weaned *Tenyi Vo* pigs given a diet supplemented with nutgall (*Rhus samialata*) fruit. However, the findings of Aphirakchatsakun *et al*. (2008) [4] observed no significant difference in average daily feed intake in crossbred post-weaned pigs given dietary supplementation at levels of 0, 4, 8 and 12% of Roselle (*Hibiscus sabdariffa*) calyx which contradicts with the results of the current study. The differences in the findings may be due to the differences in the pig breed, level of supplement given and feeding management.

Table 5: Effect of Roselle calyx powder on the feed intake of *Tenyivo* pig

Weekly Body weight gain (kg)									
Treatment	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**
T_1	0.83^a	0.95^a	1.05^a	1.17^{ab}	1.22^{ab}	1.03^b	1.58^a	1.62^b	1.75^b
T_2	0.80^a	0.88^a	1.02^a	1.07^b	1.13^b	1.33^{ab}	1.30^b	1.43^b	1.56^c
T_3	0.83^a	0.90^a	1.01^a	1.05^b	1.20^b	1.21^b	1.39^b	1.45^b	1.64^{bc}
T_4	0.86^a	0.98^a	1.04^a	1.26^a	1.33^a	1.62^a	1.60^a	1.88^a	2.31^a
SEm±	0.02	0.04	0.04	0.04	0.04	0.13	0.06	0.07	0.06
CD (P=0.05)	0.83^a	0.95^a	1.05^a	1.17^{ab}	1.22^{ab}	1.03^b	1.58^a	1.62^b	1.75^b

Note: NS = Non-significant at 5%

[a, b, c] Means bearing different superscripts in a column differ significantly.

Feed Conversion Efficiency

The effect of Roselle in weekly feed conversion efficiency of *Tenyivo* pigs from the commencement of the experimental work up to the ninth week is given in Table 6. The average feed conversion efficiency in the first week of the experimental work in T_1, T_2, T_3 and T_4 were recorded as 4.17, 4.47, 4.47 and 4.26, respectively. The corresponding feed conversion efficiency of the animals in the second and third week of the experimental work were 4.12, 4.54, 4.08, 4.37 and 3.56, 4.69, 4.53 and 3.93, respectively, with non-significant (p>0.05) difference among the treatment groups. In the fourth week, least value of 2.95 was recorded in T_4 which differed significantly (p<0.05) from group T_1 and T_2. No significant difference among the treatment groups were observed in the fifth week. The values of FCE in the sixth week was recorded as 3.54, 4.66, 3.85 and 3.35 with T_1 and

T_4 significantly differing from group T_2 groups. In the seventh week, T_4 had better (p<0.05) FCE in comparison with other treatment group with 2.90 recorded value. During the eighth week, no significant difference was recorded among the treatment groups, however, the feed conversion efficiency at the end of the experiment was recorded as 3.98, 4.24, 4.04 and 3.36 with T_4 having a better (p<0.05) feed conversion efficiency followed by T_1, T_3 and T_2. The overall feed conversion efficiency (FCE) recorded was 3.85, 4.38, 4.17 and 3.67 for T_1, T_2, T_3 and T_4, respectively with the lowest value in the group supplemented with 1.5% Roselle *i.e.* T_4group. The observations of the present experimental study were in line with the findings of Aphirakchatsakun *et al.* (2008) [4] who also reported a better feed conversion efficiency in post-weaning pigs given a diet supplemented with Roselle (*Hibiscus sabdariffa*) than those fed with control diet. Zhou *et al.* (2013) [40] also stated that growing-finishing pigs given dietary supplementation of *Coptis Chinensis* recorded better feed conversion efficiency. However, the observations of the current study were inconsistent with the observations of Lei *et al.* (2018) [24] who reported no significant difference in gain to feed ratio in growing-finishing pigs given dietary supplementation of natural and ferment herbs throughout the experimental period. The differences in the findings may be due to the type and composition variation in the test materials.

Table 6: Effect of Roselle calyx powder on the feed conversion efficiency of *Tenyivo* pig

Feed conversion efficiency (FCE)									
Week	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**
T1	4.17^{a}	4.12^{a}	3.56^{a}	4.33^{ab}	3.75^{a}	3.54^{b}	4.01^{a}	3.19^{a}	3.98^{a}
T2	4.47^{a}	4.54^{a}	4.69^{a}	4.46^{a}	4.15^{a}	4.66^{a}	3.78^{a}	4.46^{a}	4.24^{a}
T3	4.47^{a}	4.08^{a}	4.53^{a}	3.68^{bc}	4.50^{a}	3.85^{ab}	4.45^{a}	3.92^{a}	4.04^{a}
T4	4.26^{a}	4.37^{a}	3.93^{a}	2.95^{c}	3.94^{a}	3.35^{b}	2.90^{b}	4.01^{a}	3.36^{b}
SEm±	0.16	0.30	0.30	0.25	0.32	0.29	0.25	0.14	0.19
CD (P=0.05)	NS	NS	NS	0.75	0.97	0.88	0.76	NS	0.57

Note: NS = Non-significant at 5%

[a, b, c] Means bearing different superscripts in a column differ significantly.

Morbidity and Mortality rate

Through the observations made during the experimental work, it was noted that two animals marked as A3 and B5 from different treatment groups T_1 and T_2, respectively showed signs of weakness. The clinical observations recorded rectal temperature of 103ºF and 102.74ºF in A3 and B5, respectively. The animals appeared to be lethargic during the observational period coupled with loss of appetite, watery eye discharges, vomiting, diarrhea and labored breathing; reduced feed consumption and water intake was also noted. The sick animals were given glucose water orally. The experimental animal marked as B5 recovered, however, animal marked as A3 from treatment group T_1 further abstained from eating the feeds provided and succumbed to death giving an overall mortality rate of 5%. Morbidity of 10% was recorded during the entire experimental period. The dead piglet was then handed over to the ICAR-AICRP on pig Nagaland for post-mortem. Mortality of 20% in *Tenyivo* pigs was also reported in a study conducted by Amer *et al.* (2023) [2] indicating that mortality in piglets is not uncommon in control as well as in treatment group. The variation in the mortality percentage could be due to differences in the management practices and seasonal effects which are in to the observations of the current study.

Economics of pig production

The detailed economics of rearing *Tenyivo* pig throughout the research period using Roselle (*Hibiscus sabdariffa*) calyx as a diet supplement. The expenditure incurred by cost of feed per piglet was Rs. 358.98, Rs.335.40, Rs.338.91and Rs. 406.48for treatment T_1, T_2, T_3 and T_4, respectively. The corresponding total cost of production was Rs. 3526.88, Rs. 3503.57, Rs. 3507.35 and Rs. 3575.35, respectively which was inclusive of the cost of piglets, feed, Roselle calyx powder, labor charges, electricity, water and miscellaneous cost.

As indicated in the Table 3, the total returns through sale of live pigs, gunny bags and manure for T_1, T_2, T_3 and $T_4$was Rs. 3967.95, Rs. 3621.40, Rs. 3696.80 and Rs. 4469.36, respectively. The profit per piglet and profit per kilogram live weight was Rs. 441.07, Rs. 117.83, Rs. 189.45, Rs. 894.01and Rs. 65.56, Rs.19.22, Rs. 30.26, Rs. 117.76for T_1, T_2, $T_3$and T_4, respectively with the maximum value in T_4 followed by T_1, T_3 and T_2. Higher benefit cost ratio (B.C.R) of 1.25 was noted in T_4 group which has an inclusion of 1.5% Roselle calyx. This result is consistent with the findings of Amer *et al.* (2022) [1] who also reported higher profit per piglet and higher B.C.R. which indicates that inclusion of locally available herbs and medicinal plants in the diet of pigs can maximize profit with minimal input cost on dietary supplements owing to its abundance.

Conclusion

On the basis of the results obtained during the experimental study statistical analysis revealed that treatment group T_4 recorded significantly higher (p<0.05) final body weight followed by T_1, T_3 and T_2 treatment group. The final average gain in weight was higher (p<0.05) in treatment group T_4 as compared to other treatment groups. The total feed intake and average weekly feed intake was found to be higher in T_4treatment group. Better overall feed conversion efficiency was observed in treatment group T_4 which had the lowest value of 3.67 among the treatment groups. The maximum profit per piglet as well as per kg live weight was observed in T_4 followed by T_1, T_3 and T_2. Higher benefit cost ratio (B.C.R) of 1.25 in T_4 was noted. From the present study, it can be concluded that Roselle (*Hibiscus sabdariffa*) calyx powder supplemented at a level of 1.5% in the diet of *Tenyivo* pigs had better overall performance in terms of final body weight, body weight gain, feed intake and feed conversion efficiency. There was better overall better performance of the animal health with nil morbidity and mortality in T_3 and T_4 groups. Based on the results of the present study, inclusion of Roselle (*Hibiscus sabdariffa*) at 1.5% of feed can be recommended for farmers to achieve better growth rate, desirable feed intake, overall better feed conversion

efficiency, reduced morbidity, mortality rate and maximized profit.

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