Can banana peel and sweet potato vines have efficient in diets for growing rabbits?

Diuly Bortoluzzi Falcone (diuly_bortoluzzi@hotmail.com)
Universidade Federal de Santa Maria https://orcid.org/0000-0002-9817-6885
Ana Carolina Kohlrausch Klinger
Universidade Federal de Santa Maria
Stéfane Sauzem Silva
Universidade Federal de Santa Maria
Taida Juliana Adorian
Universidade Federal de Santa Maria
Geni Salete Pinto de Toledo
Universidade Federal de Santa Maria
Leila Picolli da Silva
Universidade Federal de Santa Maria

Research Article

Keywords: animal nutrition, by-products, rabbits breeding, sustainability

Posted Date: March 31st, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2617310/v1

Version of Record: A version of this preprint was published at Tropical Animal Health and Production on August 15th, 2023. See the published version at https://doi.org/10.1007/s11250-023-03697-y.

Abstract

This study aimed to evaluate the use of banana peel (BP) and sweet potato vines (SPV) as a replacement for maize and alfalfa hay in diets for rabbits. Animal performance, economic analyses, meat composition and color were evaluated for 49 days in a total 50 New Zealand White rabbits weaned at 35 days with average body mass of ±614g. The animals were allotted, in a completely randomized design, into five dietary groups: control diet (0) – without banana peels and sweet potato vines; or experimental diets: 25, 50, 75 and 100 – with 25%, 50%, 75% and 100% of banana peels and sweet potato vines in substitution to maize and alfalfa hay, respectively. Data were compared by ANOVA followed by Tukey test ($p<0.05$). Results indicate that daily feed intake, mass gain and feed conversion were similar. In addition, the study shows no differences were observed in centesimal compositions and muscle color. The replacement of maize and alfalfa hay by the combination of BP and SPV resulted in reduction in feed costs, reaching 50% in the experimental diet with 100% of substitution the ingredients. It can be concluded, based on the results on animal performance, meat/color composition and economic analyses that BP and SPV may be used as a substitute for maize and alfalfa hay up to 100% in diets for growing rabbits.

Introduction

The future of food and agriculture faces uncertainties which raise serious questions and concerns regarding their performance and sustainability (FAO, 2018). In this respect, research with an emphasis on meeting the global needs of food security and new destinations for agro-industrial by-products must be approached in a rational way, maximizing social opportunities and minimizing environmental impacts.

In developing countries, most ingredients used in rabbit farming are grown in agricultural areas which could be used to grow food for human population (Klinger et al., 2018). In this scenario, it is not logical for ingredients such as alfalfa hay and corn be used to feed rabbits in famine-stricken countries. In this context, the rabbit appears as a promising alternative, since it is an animal that can be fed with agro-industrial by-products in order to produce meat of high nutritional value (Gidenne, 2016), reducing competition with human feeding.

In agricultural communities, rabbits are traditionally used for subsistence and are fed with simplified diets, based on ingredients considered agro-industrial by-products (Khalil, 2010; Oseni and Lukefahr, 2014), such as banana peel (BP) and sweet potato vines (SPV). Bananas (*Musa spp.*) and sweet potatoes (*Ipomoea batatas*) are crops which are widely consumed and produced, mainly in developing countries (FAOSTAT, 2017), and these crops have great economic and social importance, however, their BP and SPV by-products are generally discarded.

In this context, research on the efficient use of agro-industrial by-products – such as BP and SPV – is relevant, especially in poorer communities. This way, it is possible to minimize food insecurity, reduce costs and achieve environmental sustainability in production systems. Due to these data, this study aimed to evaluate performance, meat parameters and economic viability of rabbits fed diets containing different levels of BP and SPV in substitution to maize and alfalfa hay.

Materials And Methods

This study was approved by the Biosecurity and Ethics Committee in Animal Experimentation – Project number 5914171120/2021.

Animals And Location

A total of 50 New Zealand White rabbits, males and females, weaned at 35 days of age and weighing on average ± 614g, were randomly assigned to one of the five experimental groups (ten rabbits/group), the animals were allotted into individual cages, which measured 50x50x40cm, with ceramic feeders and drinkers.

The bioassay was carried out in Cuniculture Laboratory – Department of Animal Production, unit at the main campus of the Federal University of Santa Maria (UFSM) Santa Maria, RS, Brazil – located at 29°41’S latitude, 53°48’W longitude. The animals were kept in a closed room with no control of temperature and humidity. No artificial light schedule was applied.

Experimental Diets And Feeding Management

The banana peels (BP) were obtained free of charge at the University Restaurant (RU – UFSM), where ± 45kg are produced weekly, and sweet potato vines (SPV) were obtained from a farm which focuses on biodiesel production. The BP and SPV used in the diets – of the Nanica and BRS-Cuia variety, respectively – were previously dried in forced-air circulation at 55°C-60ºC for 72h. Diets were formulated to contain a similar crude protein and fiber content (Table 1) and to comprise with growth requirements for growing rabbits (AEC, 1987).

Rabbits were offered *ad libitum* one of the five experimental diets non-peletized, until the end of the experiment at 84 days of age. Fresh water was always available. During the experimental period, body mass and feed consumption were registered weekly, in accordance with the guidelines for applied nutrition in rabbits (Fernandez-Carmona et al., 2005).

Five mash diets were formulated. The control diet (0) without BP and SPV; (25) experimental diet with 25% BP and SPV as maize and alfalfa hay substitute; (50) experimental diet with 50% BP and SPV as maize and alfalfa hay substitute; (75) experimental diet with 75% BP and SPV as maize and alfalfa hay substitute; and (100) experimental diet with 100% BP and SPV as maize and alfalfa hay substitute. No antibiotics and no synthetic amino acids for supplementation were added to diets or to the water.

Table 1
Ingredients and chemical composition of ration with banana peels and sweet potato vines in replacement to maize and alfalfa hay for rabbits.

	Experimental diets				
Ingredients (g)	0	25	50	75	100
Maize	18.00	13.50	9.00	4.50	-
Banana peels	-	4.50	9.00	13.50	18.00
Alfalfa hay	30.00	22.50	15.00	7.50	-
Sweet potato vines	-	7.50	15.00	22.50	30.00
Wheat meal	25.00	25.00	25.00	25.00	25.00
Soy-bean meal	17.00	17.50	18.00	18.00	18.05
Soy-bean oil	2.50	2.50	2.50	2.50	2.50
Rice hull	5.75	5.25	4.75	4.75	4.25
Dicalcium phosphate	0.80	0.80	0.80	0.80	0.80
Calcitic limestone	0.25	0.25	0.25	0.25	0.25
Salt	0.50	0.50	0.50	0.50	0.50
Premix*	0.20	0.20	0.20	0.20	0.20
Chemical composition of feed mixtures (%)					
Dry Matter	87.50	87.40	87.20	87.90	87.45
Crude Protein	17.71	17.54	17.52	17.35	17.27
Ash	9.52	9.60	9.85	9.90	9.95
Crude Fiber	15.16	15.28	15.47	15.61	15.83
Neutral detergent fiber	37.35	37.08	36.86	36.30	35.71
Acid detergent fiber	16.58	16.87	17.30	17.58	18.15

0: Diet without banana peels and sweet potato vines; 25, 50, 75, 100: Diets with 25%, 50%, 75%, 100% of replacement of maize and alfalfa hay for banana peels and sweet potato vines, respectively. *Premix Composition (per diet kilogram): Vitamin A 600,000 IU; Vitamin D 100,000 IU; Vitamin E 8,000; Vitamin K3 200 mg; Vitamin B1 400 mg; Vitamin B2 600 mg; Vitamin B6 200,00 mg; Vitamin B12 2,000 mg; Pantothenic acid 2,000 mg; Choline 70,000 mg; Fe 8,000 mg; Cu 1,200 mg; Co 200 mg; Mn 8,600 mg; Zn 12,000 mg; I 65 mg; Se 16 mg.

Laboratory analyses

After formulated, feed samples were dried in a forced-air oven at 55°C for 72. Then all samples were ground with a Wiley mill, to pass a 1mm screen. Dry matter was determined by oven-drying at 105°C for 24 h according to the method of the Association of Official Analytical Chemists (AOAC, 1995). The crude protein content, ash and fiber in the samples of feed, according to AOAC (1995) and crude fat (BLIGH; DYER, 1959) at the Fish Farming Laboratory, Department of Animal Science of UFSM (Table 2).

Table 2
Composition of dry banana peel (BP) and sweet potato vines (SPV).

Composition (%)	BP	SPV
Crude protein	6.70	14
Crude fiber	12	20
Fat	6.44	3
Ashes	15	11

On the 49th day of the bioassay, animals were stunned and slaughtered by jugular bleeding. The carcasses were submitted to chemical analyses to verify the contents of dry matter, crude protein and ashes at the Fish Farming Laboratory, Department of Animal Science of UFSM, according to the methods described by AOAC (1995).

Performance evaluation

For animal performance, four weighing were performed: at 35 days, 49 days, 63 days and 84 days. On the same day of weighing, the amount of feed consumed was evaluated. At the beginning of each period, a known amount of feed was provided, and at the end the leftovers were quantified. Animal and feed weights provided data to calculate the parameters of daily feed intake, daily weight gain and feed conversion.

Meat and color calculations

The carcass yield (CY) was calculated on the basis of carcass mass (CM) and animal body mass (BM) with 84 days of age, in the following equation:

$$CY\,(\%) = \frac{CM}{BM} x100$$

Color was determined through an FRU® WF-WR10QC colorimeter, with aperture size of 8 mm, illuminant D65. Fur color analysis in the meat, six measurements were taken at different points of the sample, in which the parameters of L*, a* and b* were recorded. Hue (H*) and chroma (C*) indexes were calculated on L*, a* and b* parameters (CIE, 1976). Color differences between samples (ΔE) were calculated in the following equation:

$$\Delta E_{1-2} = \sqrt{\left(a_1^* - a_2^*\right)^2 + \left(b_1^* - b_2^*\right)^2 + \left(L_1 - L_2\right)}$$

in which L_1, a_1*, b_1*, and L_2, a_2*, b_2* are the values of two different experimental groups. A variation in color (ΔE) of 2.3 units corresponds to a just noticeable difference (JND) for the human eye; higher variation is considered discernible (Mancini et al., 2019). It was operated in the CIELAB system, which uses three coordinates: the space L* indicates the luminosity, varying from white (+ L) to black (- L); chromatic coordinates a* and b*, in which a* goes from green (+ a) to red (- a), and b * varies from blue (+ b) to yellow (- b), according to CIE (1976).

Economic Analyses

The economics index of the diets was evaluated according to the prices of the ingredients of the year crop (IEA, 2021). In this case, the cost per kilo of the diets, and their respective economies, were calculated in comparison to the control diet (Table 3).

Table 3
Cost of the experimental diets

Cost per ingredient needed to produce one Kg of feed (R$)					
Ingredients	0	25	50	75	100
Maize	0.35	0.26	0.17	0.09	-
Banana peels	-	-	-	-	-
Alfalfa hay	0.90	0.90	0.90	0.90	0.90
Sweet potato vines	-	-	-	-	-
Wheat meal	0.48	0. 48	0. 48	0. 48	0. 48
Soy-bean meal	0.49	0.49	0.49	0.49	0.49
Soy-bean oil	0.13	0.13	0.13	0.13	0.13
Rice hull	-	-	-	-	-
Dicalcium phosphate	0.04	0.04	0.04	0.04	0.04
Calcitic limestone	0.0004	0.0004	0.0004	0.0004	0.0004
Salt	0.001	0.001	0.001	0.001	0.001
Premix	0.20	0.20	0.20	0.20	0.20

0: Diet without banana peels and sweet potato vines; 25, 50, 75, 100: Diets with 25%, 50%, 75%, 100% replacement of maize and alfalfa hay for banana peels and sweet potato vines, respectively. Amounts calculated based on price of 2022 crop in Brazil.

Statistical analysis

Data were conducted in a completely randomized design and each animal was considered an experimental unit. The means were compared through analysis of variance, followed by Tukey test ($P < 0.05$), with SAS statistical software (SAS, 2009).

Results

Live performance

The study shows that daily feed intake, mass gain and feeding conversion were similar ($p > 0.05$) in all five treatments (Table 4). However, there is a tendency of mass gain reduction ($p = 0.20$), as the level of inclusion of the BP and SPV increases in post-weaning phases. No animals died during the experimental period.

Table 4 Effects of replacing maize and alfalfa hay with banana peels and sweet potato vines on the performance of growing rabbits

Experimental diets							
	0	25	50	75	100	SDM	*P* value
Live weight at 35 days (g)	614	612	614	613	617	76	0.99
Live weight at 49 days (g)	1063	1100	1061	1048	1033	100	0.65
Live weight at 63 days (g)	1503	1507	1480	1468	1460	120	0.88
Live weight at 84 days (g)	2007	2018	1989	2007	1996	124	0.97
Post-weaning phase (35-49 days)							
Daily feed intake (g/d)	74.5	79.5	75.2	71.5	71.7	10.08	0.42
Daily weight gain (g/d)	32	34.90	31.90	31	30	4.46	0.20
Feed conversion (g/g)	2.35	2.25	2.36	2.33	2.41	0.30	0.93
Intermediate phase (49-63 days)							
Daily feed intake (g/d)	100.8	101.8	103	102.6	103.1	10.71	0.90
Daily weight gain (g/d)	31.40	29.07	29.95	30	30.02	4.99	0.88
Feed conversion (g/g)	3.32	3.57	3.49	3.45	3.47	0.59	0.91
Final phase (63-84 days)							
Daily feed intake (g/d)	117.3	122.8	123.1	125.6	127.4	127.8	0.77
Daily weight gain (g/d)	24.02	24.30	24.21	25.64	25.57	4.50	0.88
Feed conversion (g/g)	4.90	5.11	5.08	4.92	5.20	0.72	0.90
Total period (35-84 days)							
Daily feed intake (g/d)	100.40	104.70	103.70	103.30	104.50	10.51	0.90
Daily weight gain (g/d)	28.43	28.70	28.06	28.45	27.98	2.16	0.94
Feed conversion (g/g)	3.54	3.64	3.70	3.64	3.75	0.39	0.81

0: Diet without banana peels and sweet potato vines; 25, 50, 75, 100: Diets with 25%, 50%, 75%, 100%f replacement of maize and alfalfa hay for banana peels and sweet potato vines, respectively. SDM= standard deviation of the mean.

Meat composition and color

No differences were observed in carcass yield (CY) and centesimal compositions of meat in all five treatments (Table 5). Likewise, no differences were observed in L*, a* and b* parameters. However, a small difference among colors (ΔE) was detected (Table 6). The ΔE was higher than 2.3 units – a JND for the human eye – in the *longissimus dorsi* $\Delta E_{0\text{-}75}$ and $\Delta E_{50\text{-}75}$.

Table 5 Post-slaughter data of carcass yield and centesimal compositions of meat.

	Experimental diets					
	0	25	50	75	100	*P* value
Carcass						
Carcass mass (g)	970	1024	1054	1056	1054	0.43
Carcass yield (%)	51	52	53	52	54	-
Meat composition *(shoulder)*						
Water (%)	77.20	76.80	77.20	77.30	77.10	-
Protein (%)	19.86	19.41	19.56	19.81	19.15	-
Ashes (%)	3.50	3.70	3.80	3.70	3.90	-

0: Diet without banana peels and sweet potato vines; 25, 50, 75, 100: Diets with 25%, 50%, 75%, 100%f replacement of maize and alfalfa hay for banana peels and sweet potato vines, respectively.

Table 6 Post-slaughter data of meat color and parameters.

	Experimental diets					
	0	25	50	75	100	*P* value
Color *(Longissimus dorsi)*						
L*	53.50	52.70	54.20	51.30	52.80	0.33
a*	8.80	10.10	9.80	9.70	10.20	0.31
b*	-4.20	-3.50	-4.10	-4.50	-4.03	0.85
Differences between samples						
	x					
	0	25	50	75	100	
$\Delta E_{0\text{-}x}$	-	1.56	1.13	2.35[a]	1.36	-
$\Delta E_{25\text{-}x}$	-	-	1.69	1.85	0.64	-
$\Delta E_{50\text{-}x}$	-	-	-	2.96[a]	1.36	-
$\Delta E_{75\text{-}x}$	-	-	-	-	1.76	-
$\Delta E_{100\text{-}x}$	-	-	-	-	-	-

[a]Value over the threshold (2.3 points) with a noticeable difference in color between the samples.

Economic analyses

Results for economic analysis indicate the inclusion of banana peels (BP) and sweet potato vines (SPV) in diets for growing rabbits reduces cost (Figure 1). BP and SPV inclusion resulted in saving 12.5%, 25%, 37.5% and 50% in diets containing 25%, 50%, 75% and 100% of BP and sweet potato vines in substitution to maize and alfalfa hay, respectively.

Discussion

Live performance

According to FAO (2017), the planet Earth is reaching stages of stagnation of arable areas, and the productive emphasis relies only on the main product, with little or no importance for the by-products and waste. In this context, our results are aligned with the recommendations of FAO (2017), where BP and SPV - alternative ingredients - have great potential for applicability, in addition to assisting in the use of residual biomass and promoting the mitigation of the environmental impact.

The inclusion of banana peel (BP) and sweet potato vines (SPV), and their advantages and benefits in animal feeding, have been studied by several researchers in recent years (Gakige, et al. 2020; Galla, et al. 2020; Sugiharto, et al. 2020; Shumye et al. 2022). Our results indicate that it is possible to completely replace corn and alfalfa hay by the combination of BP and SPV in rabbit feeds. This becomes clear when we observe that daily feed intake, daily weight gain and feed conversion were not influenced by the substitution levels tested (Table 2), indicating the animals' high adaptability to the use of alternative ingredients. Studies performed by Falcone et al. (2020) already indicated the possibility of using BP to replace maize in rabbit diets. Similarly, Klinger et al., (2018) demonstrated that SPV can be used in place of alfalfa hay. Both authors report that the use of these ingredients is feasible and that they can replace conventional ingredients by 100%.

The use of banana peel and sweet potato vines stand out as agroindustrial residues in animal production, also of having wealthy resources in their chemical composition. This can be observed by the performance of growing rabbits, where there were different substitutions of maize and alfalfa hay, conventional ingredient most used in diets for rabbits in Brazil, by residues that have similar composition.

It should be pointed out that banana peel and sweet potato vines are show great potential for applicability and interconversion efficiency in animal protein, as demonstrated by our study. In this way, using cultural residues appears as an alternative to reduce environmental impacts while alleviating that mitigates the food insecurity. This practice can convert less noble plant products for human nutrition – such as BP and BBD – in excellent quality protein, such as rabbit meat.

Rehman and Shahet (2020) studied the effect of replacing maize with BP in four diets with different levels on the performance of growing rabbits. Authors report that the use of this ingredient is advantageous due to its performance data. Also, Luyen and Preston (2012) have studied the effects of performance in rabbits submitted to two feeding systems: SPV supplemented with rice husks; and guinea grass with commercial concentrate at different levels. These authors have concluded that with treatments containing SPV and rice husks, the animals were able to achieve higher rates of growth than with treatments containing guinea grass and concentrate. In this context, diets for rabbits fattening based on residues from vegetal cultures, such as BP and SPV, were established in developing countries, where these helped a lot of families to fight under nutrition (Khalil & Bolet 2010, Oseni & Lukefahr, 2014).

Meat composition and color

Another result that demonstrates the potential use of BP and SPV as substitutes for maize and alfalfa hay is the fact that the replacement levels tested did not alter the composition of rabbit meat. In this perspective, Falcone et al. (2019) evaluated carcasses of rabbits fed different levels of partial substitution of maize for BP (from 25–50%). They checked similar nutritional quality, which indicates that BP does not change carcass mass and yield, nor percentage of meat protein. Also, Klinger et al. (2017), evaluating the carcass of rabbits fed with different levels (10% and 15%) of SPV used as alfalfa hay substitute found that the treatments did not alter the weight of the carcass or percentages of fat and protein in meat.

The color carcasses is important sensory evaluation by which consumers often base product selection and judge quality (Ruiz-Capillas et al. 2021). In this context, it is important to analyze the color of the meat, since the ingredients have different levels of nutrients in their composition, such as carotenoids, which may or may not interfere with the final product. In this case, Punnet (1923) comment that dietary xanthophyll – group of carotenoids – pigments deposited in the epidermis are primarily responsible for skin color.

Regarding about it, our results indicate that there were no differences among L*, a* and b* indexes, which show that including BP and SPV does not interfere in coloration indexes. However, little differences in (ΔE) point out that some little variation happened among treatments. In this sense, according Wang et al. (2016) the meat color depends on numerous variables. Probably, this variation is not related to BP and SPV because it did not happen in a homogeneous way, and it was very subtle. In addition, it is noteworthy that only a well-trained person would be able to notice the aforementioned differences.

Economic Analyses

Several researchers have studied the use of agro-industrial residues in animal feed and its economic viability in recent years (Nascimento et al. 2021; Vastolo et al. 2021; Landim et al. 2022). Thus, it is important to highlight that the replacement of maize and alfalfa hay by the combination of BP and SPV was able to cause a great reduction in feed costs, this becomes clear when we observe Fig. 1, where there was a reduction in feed costs, reaching 50% in the experimental diet with 100% BP and SPV replacement of the ingredients.

Studies related to costs already indicated the economic viability, Falcone et al. (2019) and Omole et al. (2008), in their research about including BP in diets for rabbits, report that there was a decrease in food cost according to the level of banana. Also, Klinger et al. (2019), in their study about including SPV in diets for rabbits, concluded the existence of economic viability economic while using these ingredients. Both authors emphasize that maize and alfalfa hay, an important energy and fiber source, respectively, are expensive ingredients. In this context, using residues in diets for rabbits represents a viable strategy for production because of the possibility to reduce food costs and to benefit the environment.

Still in terms of costs, another important issue observed is the high cost of ingredients – could reach up to 70% of total costs in production – which has led to the search for non-conventional and more accessible ones (Akande, 2015, Gidenne et al., 2017). Therefore, using these residues rationally, for rabbits' nutrition, for example, to reduce environmental burden and to improve economic profit is necessary (De Blas et al., 2018). This way, human population would have access to high biological/nutritional value food – rabbit meat – in which the animals were fed with agro-industrial by-products, besides helping people to reduce expenses with food.

After this research, the finding was that by-products as banana peel and sweet potato vines, which have massive density of nutrients, can be used in diets for rabbits. In this sense, the results enable diets to be less expensive and to contain a high-quality protein. Therefore, banana peel and sweet potato vines can replace maize and alfalfa hay up to 100% in diets for growing rabbits.

Declarations

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability

Not applicable.

Acknowledgements

The authors thank the Coordination for the Improvement of Higher Education Personnel (CAPES), for the financial support for this research.

Funding

This research was funded by the Coordination for the Improvement of Higher Education Personnel (CAPES).

Author information

Affiliations

Department of Animal Science, Federal University of Santa Maria, Av. Roraima – 1000, Cidade Universitária, 97105-900, Santa Maria, RS, Brazil.

Diuly Bortoluzzi Falcone, Ana Carolina Kohlrausch Klinger, Stéfane Sauzem Silva, Taida Juliana Adorian, Geni Salete Pinto de Toledo & Leila Picolli da Silva

Contributions

DBF, GSPT and LPS conceived and designed research. DBF, SSS and GSPT conducted experiments. DBF, ACKK, TJA and LPS analysed and interpreted data. DBF wrote the manuscript. All authors read and approved the manuscript.

Corresponding author

Correspondence to Diuly Bortoluzzi Falcone

Ethics approval

This study was conducted in accordance with the Ethics Committee on The Use of Animals (CEUA) of the Federal University of Santa Maria under the protocol 05914171120/2021.

Conflict of interest

The authors declare that there was no conflict of interest

References

1. AEC,1987. Recomendações para nutrição. 5.ed. Antony, France: RHÔNE-POULENC, 86p.
2. AOAC, 1995. Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists, Washington, DC,1094 p.
3. Akande, KE. 2015. Dietary Effects of Increasing Levels of Pigeon Pea Meal on Rabbit Performance. Journal of Agricultural Science. 7,156-162. DOI: 10.5539 / jas.v7n7p156
4. Bligh, E.G.; Dyer, W.J. A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology, v.37, p.911-917, 1959.
5. CIE, 1976. Official recommendations on uniform colour spaces, colour differences equations and metric colour terms. Paris, France: Commission Internationale de l'Eclairage. Commission.
6. De Blas, JC, Ferrer P, Rodríguez, CA, Cerisuelo, A, García Rebollar, P, Calvet, S, Farias, C. 2018. Nutritive value of citrus co-products in rabbit feeding. World Rabbit Science. 26,7-14. https://doi.org/10.4995/wrs.2018.7699
7. Falcone, DB, Klinger, ACK, Knob, AN, Toledo, GSP, Silva, LP. 2019. Casca de banana e seu efeito na redução de custos e características de carcaça de coelhos de corte. Atena Editora. 1, 6-12. DOI: 10.22533/at.ed.6091915042 (in Portuguese)
8. Falcone, DB, Klinger, ACK, Toledo, GSP, Silva, LP. 2020. Performance, meat characteristics and economic viability of rabbits fed diets containing banana peel. Tropical Animal Health and Production, v. 52, p. 681–685, 2020. DOI: 10.1007/s11250-019-02057-z
9. Fernández-Carmona, J, Blas, E, Pascual, JJ, Maertens, L, Gidenne, T, Xiccato, G, García, J. 2005. Recommendations and guidelines for applied nutrition experiments in rabbits. World Rabbit Science. 13, 209–228. DOI: https://doi.org/10.4995/wrs.2005.516
10. FAO, 2017. Food and Agriculture Organization of the United Nations: Yearbook of Fishery Statistics. Food and Agriculture Organization of the United Nations, Rome
11. FAO, 2017. Faostat- Food and Agriculture Organization of the United Nations: Statistics database. Food and Agriculture Organization of the United Nations, Rome
12. FAO, 2018. Food and Agriculture Organization of the United Nations: The future of food and agriculture - Alternative pathways to 2050. Food and Agriculture Organization of the United Nations, Rome, 224pp.
13. Gakige, JK, Gachuri C, Butterbach-bahl, K, Goopy, JP. 2020. Sweet potato (*Ipomoea batatas*) vine silage: a cost-effective supplement for milk production in smallholder dairy-farming systems of East

Africa?. Animal Production Science 60, 1087-1094. https://doi.org/10.1071/AN18743

14. Galla, NA, Nampija, Z, Lutwama, V, Mayanja, S, Grant, F, Kyalo, G, Kiggundu, M, Zziwa, E, Nambi-Kasozi1, J. 2020. Effects of Inclusion Levels of Sweet Potato Vine Silage on Feed Intake, Milk Production and Profitability of Lactating Crossbred Dairy Cows. Open Journal of Animal Sciences. 10, 608-617. https://doi.org/10.4236/ojas.2020.103039
15. Gidenne, T. 2016. Le lapin. De la biologie à l'élevage. Quae (Ed), Versailles, França, p.270
16. Gidenne, T, Garreau H, Drouilhet L, Aubert C, Maertens L. 2017. Improving feed efficiency in rabbit production, a review on nutritional, technico-economical, genetic and environmental. Animal Feed Science and Technology. 225,109-122. https://doi.org/10.1016/j.anifeedsci.2017.01.016
17. IEA, 2022. **Instituto de Economia Agrícola - Banco de dados. São Paulo, Brazil.** (in Portuguese)
18. Khalil, MH, Bolet, G. 2010. Sustainable rabbit breeding and genetic improvement programs achieved in developing countries. In: 9th World congress on genetics applied to livestock production. Leipzig, GE. DOI: 10.13140 / 2.1.2155.6161
19. Klinger, ACK, Silva LP, Toledo GSP, Galarreta B, Goulart F. 2017. Effect of sweet potato vines on performance parameters and some carcass characteristics of rabbits. Journal of Animal Physiology and Animal Nutrition. 102, 152–156. https://doi.org/10.1111/jpn.12672
20. Klinger, ACK, Silva, LP, Toledo, GSP, Falcone, DB, Goulart, FR. 2018. Sweet potato vines in diets for growing rabbits on performance, carcass characteristics and meat quality. Animal Science Journal. 89, 1556–156. https://doi:10.1111/asj.13105
21. Klinger, ACK, Falcone, DB, Toledo, GSP, Silva, LP. 2019. Baraço de batata doce como redutor de custos em dietas para coelhos. Atena Editora. 1, 1-5. DOI: 10.22533/at.ed.6091915041 (in Portuguese)
22. Landim, A.V., Silveira, R.M.F., de Oliveira, J.R.R. et al. 2022. Bioeconomic analysis of total replacement of corn grain with by-product from biscuit manufacture for purebred and crossbred Morada Nova lambs in feedlot system in the Brazilian semi-arid region. Tropical Animal Health Production. 54, 1-11. https://doi.org/10.1007/s11250-022-03314-4
23. Luyen, LT., Preston, TR. 2012. Growth performance of New Zealand White rabbits fed sweet potato (*Ipomoea batatas*) vines supplemented with paddy rice or Guinea grass supplemented with commercial concentrate. Livestock Research for Rural Development 24, 6–9.
24. Mancini, S, Minieri, S, Buccioni, A, Cossato, MMF, Russo, C, Paci, G. 2019. The influence of dietary chestnut and quebracho tannins mix on rabbit meat quality. Animal science journal. 90, 680-689. https://doi.org/10.1111/asj.13194
25. Nascimento, J, Ponciano, NJ, Alfaiate, MB, Vidal Junior, MV, Matos, MB, Pereira Junior, G, Bila, CRFC, Andrade, DR, Gravina, GA, Daher, RF. 2021. Economic Viability of Cassava Residues in the Nile Tilapia Diet. 13,118-126. https://doi.org/10.5539/jas.v13n11p118
26. Omole, A J, Ajasin, FO, Oluokun, JA, Obi, OO. 2008. Performance characteristics of weaned rabbit fed plantain peel as replacement for maize. Nutrition & Food Science. 38, 559-563. https://doi.org/10.1108/00346650810920169

27. Oseni, SO, Lukefahr, SD. 2014. Rabbit production in low-input systems in Africa: situation, knowledge and perspectives – A review. World Rabbit Science. 22,147-160. https://doi.org/10.4995/wrs.2014.1348
28. Punnet, R. C. 1923. Page 113 in Heredity in Poultry. Macmillan, London.
29. Rehman, A, Shahet, Z. 2020. Effects of banana peels on growth performance, dry matter digestibility and feed efficiency of growing male rabbits. European International Journal of Science and Technology, 9, 19-28.
30. Ruiz-Capillas C, Herrero AM, Pintado T, Delgado-Pando G. 2021. Sensory Analysis and Consumer Research in New Meat Products Development. Foods. 10, 1-15. https://doi.org/10.3390/foods10020429
31. SAS, 2009. Statistical Analyses System. User's guide: Statistics. Version 9.0. SAS Institute, Cary, NC, USA.
32. Shumye, M, Molla, M, Awoke, T, Dagnew, Y. 2022. Effect of banana peels as a substitute for white maize grain on laying performances and egg quality of Bovans Brown chickens. Cogent Food & Agriculture, 8, 1-11. https://doi.org/10.1080/23311932.2022.2116803
33. Sugiharto, S, Yudiarti, T, Isroli, I, Widiastuti, E, Wahyuni, HI, Sartono, TA. 2020. Growth performance, hematological responses, intestinal microbiology and carcass traits of broiler chickens fed finisher diets containing two-stage fermented banana peel meal. Tropical Animal Health Production. 52, 1425–1433. https://doi.org/10.1007/s11250-019-02147-y
34. Vastolo, A, Calabrò, S, Cutrignelli, MI. 2022. A review on the use of agro-industrial CO-products in animals' diets. Italian Journal of Animal Science. 21, 577-594. https://doi.org/10.1080/1828051X.2022.2039562
35. Wang, J, Su, Y, Elzo, MA, Jia, X, Chen, S, Lai, S. 2016. Comparison of Carcass and Meat Quality Traits among Three Rabbit Breeds. Korean Journal Food Science Animal Resources. 36, 84–89. http://dx.doi.org/10.5851/kosfa.2016.36.1.84

Figures

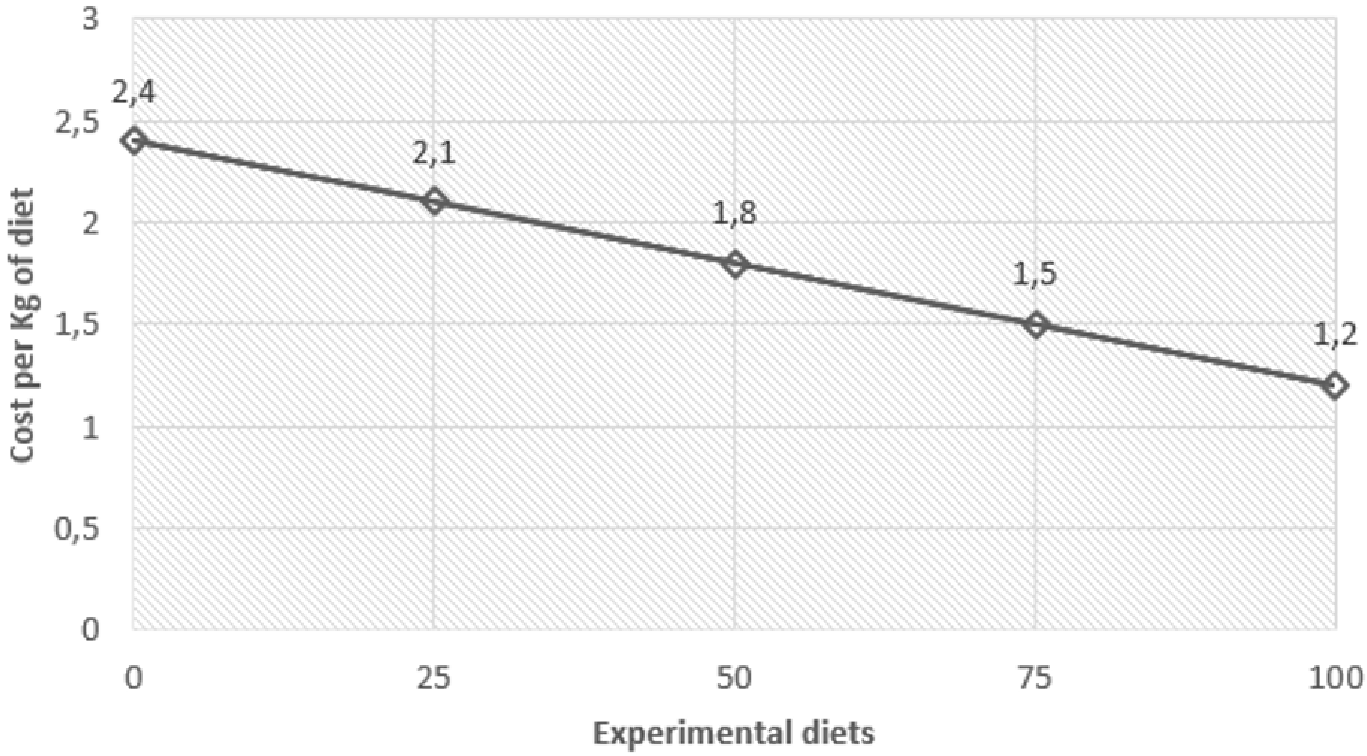

Figure 1

Economic viability of the experimental diets