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Research Article

Effect of Dietary Sacha Inchi Pressed Cake as a Protein Source on Guinea Pig Carcass Yield and Meat Quality

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Abstract

Objective: This study was conducted to assess whether substituting sacha inchi pressed cake for soy pressed cake as a protein source improved the carcass yield and meat quality of guinea pigs. **Materials and Methods:** Using a completely randomized block design, seventy two 15 day-old guinea pigs were distributed in two blocks (male-female) and three treatments: diet including soy-pressed cake (DS); diet including soy pressed cake and sacha inchi pressed cake (DSSI) and diet including sacha inchi pressed cake (DSI). The animals were distributed into 18 groups of four guinea pigs each. At the end of the 10 week experimental period, we evaluated the carcass yield (CP) and assessed the meat quality as: percentage of protein (PP) and fat (PF), cholesterol content (CC) and organoleptic characteristics of the meat (OCM). **Results:** Animals fed DSSI had the best CP ($p<0.05$), whereas the DSSI and DSI groups had the lowest PF and CC ($p<0.01$). We also observed statistically significant differences between the sexes, particularly for PF and CC. In terms of OCM, meat from the DSSI and DSI groups had improved texture, palatability and fattiness relative to meat from the DS group ($p<0.01$). **Conclusion:** Guinea pigs fed a diet containing sacha inchi pressed cake had improved carcass yield. The meat from these animals had lower fat and cholesterol content as well as improved organoleptic characteristics.

Key words: Carcass yield, guinea pig, meat quality, protein, sacha inchi pressed-cake

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In South America, meat from guinea pigs is frequently consumed, particularly by populations living in highland areas[1]. Given that guinea pig meat represents a high-quality animal protein for domestic consumption, interest in methods to improve breeding and meat production from guinea pigs is growing[2].

Guinea pig meat is highly digestible and nutritious due to its low fat and cholesterol content, as well as the presence of essential nutrients such as arachidonic acid (AA) and docosahexaenoic fatty acid (DHA). Notably, in other meats these nutrients are either absent or present in low amounts.[3] One serving of guinea pig meat also provides 21% of the daily recommended amount of n-3 polyunsaturated fatty acids (PUFA)[4]. Guinea pig meat also has higher protein and lower fat contents relative to meat from other sources, including rabbit, goat, poultry, beef, pork and sheep[5]. Although, the typical diet of guinea pigs largely consists of kitchen food waste, the meat quality can be improved through feeding of a balanced diet[6,7].

Sacha inchi (*Plukenetia volubilis*) is a member of the Euphorbiaceae family and is also known as the sacha peanut, mountain peanut, Inca nut or Inca peanut[8]. As an emergent species, sacha inchi is a permanent and abundant crop in the Peruvian jungle[9]. Oil extracted from sacha inchi has many uses[10] and pressed cake formed as a byproduct of oil production[11] has a high carbohydrate and protein content[12]. A study by Rawdkuen *et al.*[12] reported that sacha inchi pressed cake contains 56.6, 4.13 and 30.72% protein, fat and carbohydrate, respectively and has high contents of essential amino acids such as lysine, histidine, leucine as well as isoleucine, valine, tryptophan and phenylalanine. Sacha inchi pressed cake also has high amounts of omega-3 and omega-6 fatty acids in addition to potassium, phosphorus and magnesium.

The good nutritional value of sacha inchi pressed cake suggests that it may be suitable for inclusion in animal feed, although few studies have examined whether it has beneficial effects on products derived from animals. Here we examined whether meat from guinea pigs fed a diet that includes sacha inchi pressed cake had improved carcass yield and characteristics.

MATERIALS AND METHODS

The breeding phase of the experiment was carried out on a farm located in northern Peru in the district of Moche, province of Trujillo, department of La Libertad. Carcass yield and meat quality tests were conducted at the Animal Nutrition Laboratory of the Faculty of Agricultural Sciences. This study was approved by an animal ethics committee and followed the National University of Trujillo code of ethics for research.

Animals, diets and experimental design: A total of seventy two 15 day-old guinea pigs (36 males and 36 females) were provided by a local farm. The guinea pigs were identified and distributed randomly into 18 groups of 4 animals each and the housing density was 0.16 m^2. The animals were given a mixed feed comprising forage and concentrated feed. Three diets were formulated according to requirements recommended by Vergara[13], The soy pressed cake which supplement all the protein requirement (DS), sacha inchi pressed cake which supplement all the protein requirement (DSI) and a combination of both which each one supplement the half of protein requirement (DSSI) was used as a protein source (Table 1). The diets and water were supplied *ad libitum*.

To determine the guinea pig carcass yield, the animal was first stunned and then immediately exsanguinated via a cut in the jugular vein. The carcass was scalded in hot water (80-90°C) for 5-10 sec and washed in cold water (10-15°C) to remove remaining blood and hair. The carcass was then cut along the sagittal plane and gutted prior to measuring the total weight of the weight of the head, neck, ribs, long leg, shoulder, heart and liver. The carcass yield (CP) was determined based on the carcass weight (CW) and live weight (LW) using the equation[14]:

Table 1: Experimental diet composition and calculated analysis

	Treatments		
Ingredients (%)	DS†	DSSI	DSI
Corn	13.00	17.00	17.00
Molasses	3.00	8.00	8.00
Ground barley	40.00	17.00	4.00
Soy pressed-cake	43.00	27.00	0.00
Sacha inchi pressed-cake	0.00	27.00	68.00
Calcium carbonate	1.00	1.00	1.00
Dicalcium phosphate	0.00	2.00	3.00
Vitamin and mineral mixture*	0.05	0.05	0.05
Mycotoxin adsorbent**	0.30	0.30	0.30
Total	100.00	100.00	100.00
Calculated analysis			
Metabolism energy (kcal kg^{-1})	3000.00	3000.00	3000.00
Protein (%)	18.00	18.00	18.00
Fiber (%)	10.00	10.00	10.00
Calcium (%)	0.80	0.80	0.80
Phosphorus (%)	0.40	0.40	0.40

*Vitamin and mineral mixture (per kg diet); Vitamin A: 10,000,000 IU, Vitamin: 1,500,000 IU, Vitamin E: 10,000 IU, Manganese: 40 g, Zinc: 70 g, Iron: 50 g, Copper: 10 g, Iodine: 1 g, Selenium: 0.15 g, Cobalt: 0.15 g, Excipient: 1 g. **Mycotoxin adsorbent contains: Silicon Dioxide, Aluminum Oxide, Iron oxide, Calcium oxide, Magnesium oxide, Sodium oxide, Potassium oxide. †DS: Soy pressed cake only, DSSI: Combination of soy and sacha inchi pressed cake, DSI: Sacha inchi pressed cake only

$$CP = \frac{LW}{CW} \times 100$$

Meat quality: To evaluate meat quality, the protein, fat and cholesterol content of the meat was assessed using the Kjeldahl method[15], Soxhlet method[16] and Bialex® Direct HDL method[17], respectively.

The organoleptic quality of theme at was then evaluated by tasters who considered the odor, color, taste, juiciness, texture, palatability and fattiness. All samples were seasoned with salt and garlic, grilled and then cut into 2 cm^2 pieces. The tasters did not consume spicy foods, cigarettes or alcoholic beverages within 24 h of the test to ensure that their perceptions were not affected by these agents. The properties were scored on a scale of 1-10, with 1 being the worst and 10 the best.

Statistical analysis: An analysis of variance using one-way ANOVA corresponding to the random block design was used and a Duncan means comparison test was used for carcass yield and meat quality parameters. A non-parametric Friedman test was used to analyze the organoleptic characteristics of the meat. All statistical analyses were carried out using IBM SPSS Statistics™ software (version 22.0.0.0, IBM Corp., Armonk, New York, USA).

RESULTS

Carcass yield: The average carcass yield for the group fed DSSI was significantly higher (71.1%) compared to that for DS (70.1%) and DSI (69.70%) (p<0.05). Male animals had a higher average total carcass yield (70.7%) relative to females (69.7%; p<0.05) (Table 2).

Protein: The mean values for the percentage of protein content showed no significant differences among the different diet treatments (18.81% for both DSSI and DSI and 18.35% for DS; p>0.05). Meat from males had a higher percentage of protein (19.4%) than that from females (18.0%; p<0.05). Males fed diets containing DSSI and DSI produced meat that had a higher protein content than males fed DS, whereas the protein content of meat from females was similar among the three diets (Table 2).

Fat: The percentage of fat in the meat was clearly affected by diet as evidenced by the significantly (p<0.01) higher amount of fat in meat from animals fed DS (12.2%) compared to meat from animals fed DSI or DSSI, which had similar fat contents (7.9 and 8.11%, respectively) (Table 2).

Table 2: Mean values for guinea pig carcass yield and protein, fat and cholesterol content of the meat

	Treatments		
Parameters	DS †	DSSI	DSI
Carcass yield (%)			
Female	69.18	70.77	69.75
Male*	71.03	71.33	69.63
Total	70.10^b	71.14^a	69.70^b
Protein (%)			
Female	17.93	17.97	17.99
Male**	18.76	19.65	19.63
Total	18.35	18.81	18.81
Fat (%)			
Female	12.84	09.85	09.55
Male**	11.56	06.31	06.30
Total	12.20^a	08.08^b	07.93^b
Cholesterol (mg dL^{-1})			
Female	33.33	30.31	30.25
Male**	90.43	63.80	60.40
Total	61.88^a	47.06^b	45.33^b

Statistically significant differences: *p<0.05, **p<0.001 vs. Female. [a,b]Means having different superscripts differ significantly (p<0.05), † DS: Soy pressed cake only, DSSI: Combination of soy and sacha inchi pressed cake, DSI: Sacha inchi pressed cake only

Table 3: Mean values for evaluation of organoleptic properties of guinea pig meat

	Treatments		
Characteristics	DS †	DSSI	DSI
Odor	8.9	9.0	9.0
Color	8.0	8.2	8.5
Taste	9.5	9.6	9.8
Juiciness	8.5	8.9	8.7
Texture	1.5^a	9.1^b	9.6^b
Palatability	7.8^a	9.7^b	9.7^b
Fattiness	7.0^a	8.0^b	9.0^c

[a,b,c]Means with different superscripts differ significantly (p<0.05) † DS: Soy pressed cake only, DSSI: Combination of soy and sacha inchi pressed cake; DSI: Sacha inchi pressed cake only

Cholesterol: The addition of soy cake or sacha inchi cake also influenced the cholesterol content of guinea pig meat. Animals fed the DS treatment produced meat that had the highest cholesterol content (61.9 mg dL^{-1}), which differed significantly (p<0.01) from the similar values seen for the DSI and DSSI treatments (45.3 and 47.1 mg dL^{-1}, respectively) (Table 2).

Organoleptic properties: The scores for the organoleptic characteristics odor, color, taste and juiciness were high and similar for meat from animals fed DS, DSSI and DSI (p>0.05). In particular, meat from all three treatment groups was judged by the panelists to have favorable color and taste. Juiciness also ranked high among the three diets (p>0.05) (Table 3).

Scores for meat texture did vary among the treatments, with meat from animals fed DSI and DSSI diets judged to have significantly better texture relative to that for DS ($p<0.01$) (Table 3). A similar pattern was seen for palatability scores. Meanwhile, meat from animals in the DSSI and DSI treatment groups was associated with higher acceptance (palatability) compared to the DS group ($p<0.01$). In terms of meat fattiness, DSI was judged to be superior to DSSI and both had better scores than the DS treatment ($p<0.01$) (Table 3).

DISCUSSION

Carcass yield: Our results for carcass yield ranged between 69.4 and 71.1%, which is consistent with a previous study by Morales[18] that reported a yield of 71% but lower than that reported by Chauca *et al.*[19]. This difference could be because we included the lungs, spleen and kidneys in our calculations of carcass yield. In a study to examine the effects of soy cake in guinea pig diets, Carbajal[20] observed higher carcass yields (75.1, 74.1 and 72.4%) for three types of diets that included soy cake. Similarly, Arbulú *et al.*[21] found carcass yields of 67, 70 and 74% for guinea pigs fed mixed diets comprising 70% balanced diet and 30% forage and Huamaní *et al.*[14] reported a 72.7% carcass yield. Notably, we found that carcass yield could be influenced by diet, sex, parts included in weight measurements and age, which is consistent with Chauca[22] who found that carcass yield increased with age due to increased deposition of fat and muscle in the carcass while the organ size remained essentially constant. Similar to findings reported by Carrazco[23], here we observed that males had a higher carcass yield than females, likely because males have a higher capacity to convert the food consumed into meat, which accelerates development and allows higher weight gain rates during the growth stage. However, Arbulú *et al.*[21] did not find differences between sexes, so the contribution of sex to carcass yield in animals fed different diets remains unclear. We also found that animals fed the DSSI diet, which combined the soy and sacha inchi cakes, had the highest carcass yield. In this diet, tannins present in soy and sacha inchi could form complexes with numerous different molecules involved in protein and carbohydrate digestion. Meanwhile, sacha inchi pressed cake has a lower content of trypsin inhibitors compared to soy, so the combination of both soy and sacha inchi could improve nutrient digestion, which would translate to a higher carcass yield.[11] Moreover, sacha inchi pressed cake was reported to have lower palatability that reduces the consumption rate[24]. Thus, in addition to improving nutrient digestion, the combination of soy and sacha inchi as a protein supplement could ensure appropriate consumption rates[25]. Additional study will be needed to validate these possibilities.

Protein: Although, the three diet treatments showed no differences in protein content of meat from females, meat from males fed the DSSI and DSI diets tended to have a higher protein content relative to the DS treatment. This difference could be due to sex-related or genetic differences as well as the lower fat content of the DSSI and DSI diets, which is consistent with findings of Quispe[26], who showed that protein content in meat is inversely related to the fat content of the diet. Flores-Mancheno *et al.*[27] suggested a role of genetics in meat protein content and reported that meat from Creole guinea pigs had a higher protein content (19.4%) than that of Andean and Peruvian guinea pigs (18.55 and 17.78%, respectively). These authors also found a correlation between high protein level (19.1%) and lower fat content (7.6%) in Creole guinea pigs[27].

Fat: Dietary fat also affects the carcass quality, as reported by Huamaní *et al.*[14]. Arbulú *et al.*[21]. reported that age at slaughter is associated with lower fat content in meat, as younger animals tend to deposit more protein rather than fat[21]. Meat from male animals also had a lower fat content than that from females, particularly for the DSSI and DSI diets. These results are consistent with those of Arbulú *et al.*[21] who found higher fat deposition in females. The levels of fat we observed for all diets (11.6% for DS and ~6.3% for DSSI and DSI)were lower than those observed by Guevara *et al.*[23], who reported a 13.8% fat content of meat from animals fed a diet containing 4% sacha inchi seed and 15.85% for diets that contained both1% fish oil and 4% sacha inchi seed. Fat content is an important aspect due to its contribution to meat quality, taste, juiciness and texture[28], although meat that has excessive amounts of fat is less healthy for consumption.

Cholesterol: The cholesterol content in meat from males fed the DSSI and DSI diets was significantly lower than that for males fed the DS diet (63.8 and 60.4 mg dL^{-1} vs. 90.43 mg dL^{-1}) (Table 2). This difference could be due to the lipid-lowering properties of omega-3 fatty acids in sacha inchi[10,29]. Meanwhile, meat from females had similar and lower cholesterol content across the diets (30.25-33.33 mg dL^{-1}). The values for males are similar to those reported by Guevara[24], who determined values of 66 mg dL^{-1} for meat from animals fed a diet containing 4% sacha inchi seeds. Similarly, Gorriti *et al.*[29] showed that Holtzman rats consuming 0.5 mL kg^{-1} day^{-1} sacha inchi oil had the lowest average values of total cholesterol relative to rats fed diets without sacha inchi oil.

Organoleptic characteristics of meat: Food odor plays a significant physiological role in stimulating secretion of digestive juices. Guevara *et al.*[30] found differences in meat from animals fed diets supplemented with omega-3 fatty acids from fish or sacha inchi seeds. Their results indicated that meat odor was affected to a greater degree by preservation and preparation methods such that fried meat maintained a favorable odor, whereas precooked or previously frozen meat was judged to have less desirable odors[24]. Diez *et al.*[31] reported that meat from older animals had a higher fat content as well as a more preferable odor and flavor. The color of meat can be affected by species, diet, age, sex and muscle content. Biochemical properties, including pH, storage conditions and processes associated with myoglobin oxygenation and oxidation also affect meat color[8]. However, Guevara *et al.*[24] found that supplementation with either fish oil (1%) or sacha inchi seed (4%) affected meat color. In this study, meat flavor had maximum scores among the organoleptic properties, in part due to the use of seasonings as flavor enhancers. However, as mentioned above, Guevara *et al.*[30] found that, in addition to preparation method, the preservation method also affected flavor. As such, fried guinea pig meat was found to have better flavor, whereas freezing preserved the flavor to a better degree than did re-heating of precooked guinea pig meat. Here juiciness, a characteristic that is affected by intramuscular lipids and water content, was similar among all three diets.

Meat texture is affected by muscle fibers, ante-mortem stress conditions and the distribution and type of connective or connective tissue and ashes[32]. Texture is also affected by genetics, age, sex and intramuscular fat content and is a decisive attribute for consumer acceptability[33]. Argote and Cuervo[34] determined that meat from a freshly slaughtered and grilled guinea pig was less acceptable than aged, refrigerated meat that was then baked. This preservation and preparation method had the greatest acceptance in terms of taste and texture relative to frozen and fried meat. For fattiness, meat from animals fed DSI received the highest scores. This results is consistent with that of Guevara *et al.*[35], who found that inclusion of a non-traditional protein source [2% pajuro flour (*Erythrina edulis*)] in guinea pig feed, produced meat that was judged to be less fatty, which may be due to the high protein content of pajuro flour and the lean carcasses seen with this diet. Moreover, Cisneros and Guevara[36] reported a low percentage of fat in meat from guinea pigs fed a diet supplemented with stevia powder (*Stevia rebaudiana bertoni*) as a non-traditional protein source. Together these results indicate that higher amounts of dietary protein can produce a lower fat content in the carcass.

CONCLUSION

DSSI and DSI treatments were associated with sex-specific improvements in both guinea pig carcass yield and meat quality, particularly in terms of lower fat and total cholesterol content. Among organoleptic characteristics, meat odor, color, flavor and juiciness were not affected by the addition of sacha inchi pressed cake but scores for texture, acceptability and fattiness were all higher for meat from guinea pigs fed a diet containing sacha inchi pressed cake.

SIGNIFICANCE STATEMENT

This study found that supplementation of guinea pig diets with sacha inchi pressed cake improved carcass yield and meat quality. Results from this study will provide insights into critical aspects of animal nutrition and strategies that involve byproducts such as sacha inchi pressed cake to improve meat characteristics and yield.

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