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CHEMICAL CHARACTERIZATION AND FATTY ACID PROFILE OF SACHA INCHI FLOUR (*PLUKENETIA VOLUBILIS*) AS RAW MATERIAL, IN THE ELABORATION OF DIETS FOR ANIMAL USE.

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Graphical Abstract

Abstract.

The objective of the study was to carry out a chemical characterization and to quantify the fatty acid profile of Sacha inchi (*Plukenetia volubilis*) to be used as raw material, in the elaboration of diets for animal use. The research was developed with samples of the seed meal with and without the Sacha inchi capsule, acquired from the unused waste for export from the "Huamboya" collection center, located in the Amazon province of Morona Santiago in Ecuador. The determination of the chemical composition was analyzed the nutrients of: dry matter (DM), organic matter (OM); crude protein (CP); crude fiber (FB); grease; Nitrogen-free extracts (ELN); gross energy (EB) in the laboratory of the National Institute for Agricultural Research (INIAP). The fatty acid profile (Saturated; Polyunsaturated and Monounsaturated) was determined in the Laboratory of Analisis de Alimentos AVVE S.A., through the liquid chromatography / PDA technique. Sacha inchi seed flour with and without capsule from crops in the Huamboya canton, Morona Santiago Province, has an adequate protein for the swine species, as well as the fiber, fat and energy content are acceptable, to be used in The preparation of diets for Creole pigs in the growth and final fattening stage, in addition

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Table 1. Chemical composition of the seed of Sacha inchi (*Plukenetia volubilis*) with and without capsule.

Nutrients	Seed without capsule	Seed with capsule			
	Mean		±EE	Minimum	Maximum
Crude Protein, %	18,2	16,0	0,4	14,0	18,7
Crude fiber, %	22,2	32,6	0,22	22,0	33,4
ELN, %	31,7	-	0,92	31,0	32,8
EB, kcal/Kg MS^{-1}	5497,33	-	301,52	5306,0	5845,0
Dry matter,	-	92,02			
Organic matter, %	-	85,15			
Ash, %	-	14,55			

to the flour from the Sacha inchi seed with and without capsule, are an important source of polyunsaturated fatty acids, mainly α-linolenic acid (C18: 3 ω - 3) and linoleic acid (C18: 2 ω-6), which could provide beneficial effects due to their nutritional qualities and nutritional value, to be considered in the inclusion of diets for animal feed.

Introduction

In Ecuador, the Ministry of Agriculture y Livestock (MAG), promotes the cultivation of Sacha inchi (*Plukenetia volubilis*), also called "Maní del Inca", a product recognized for its nutrient properties and profitability, according to Briones, (2014) it is estimated that in Ecuador there are around 813 hectares of Sacha inchi concentrated in the provinces of Pichincha, Morona Santiago, Esmeraldas, Manabí and El Oro with an annual yield of 3,5 tons per hectare which in turn gives a total of 2845,5 tons per year, which can reach a peak of production in the fifth year at a yield of 5000 kilos per hectarian.

The seed of the Sacha inchi is a very popular consumer product, and the seed and oil have been part of the diet of indigenous populations since ancient times, the small farmers of the country who found in this seed an opportunity for its assured purchase Peru, the main buyer country of Sacha Inchi seed for its subsequent transformation into final products, however, poor quality seed that does not come from highly productive and healthy mother plants has not been adequately used, which can be used as raw materials to prepare diets for different species of animals, as they have a large amount of polyunsaturated fatty acids that cannot be produced by the animal body and yet are very beneficial for health Alayón and Echeverri (2016), taking into account the above can increase the nutritional value of this plant for the formulation of diets that meet the requirements of several animal species. les, that for future research it could be evaluated if these essential elements are impregnated in the meat, eggs and fat of the animals, the study was developed with the objective of carrying out a chemical characterization and quantifying the fatty acid profile of Sacha inchi (*Plukenetia volubilis*) to be used as raw material, in the preparation of diets for animal use.

Materials and Methods

The research was developed with samples of Sacha inchi acquired from waste not used for export from the collection center "Huamboya", located in the Amazon province of Morona Santiago in Ecuador, the raw material was transferred to the facilities of the "Research Center Postgraduate and Amazon Conservation ”CIPCA, for further processing.

Preparation of flour from the seed with and without a Sacha inchi capsule: Sacha inchi (*Plukenetia volubilis*) seed flour was made, it began with the selection of seeds, once the seeds were selected, they went through a pre-drying process for three days in the sun. Then, they were placed in a tumble dryer for two hours at a temperature of 65 ºC, left to cool for one hour, and finally ground in a semi-industrial mill (TRAPS brand, model TRF 300G) with a 0,25 mm mesh, they were packed in airtight sleeves and stored for five days until use.

Determination of the proximal composition of the seed meal with and without Sacha inchi capsule: Samples of the seed meal with and without the Sacha inchi capsule were analyzed in the chemistry laboratory of the Amazonian State University and in the food analysis and research service laboratory of the National Institute of Agricultural Research (INIAP), Santa Catalina, Quito, Ecuador. A random sample was taken with 2 kg of each one to analyze the chemical composition; dry matter (DM), crude protein (CP), crude fiber (FB), ashes and nitrogen-free extracts (ELN), it was considered that the organic matter content (OM) is the result of subtracting (100% ashes) , according to the procedures described by the AOAC (2005).

Profile of saturated, polyunsaturated and monounsaturated fatty acids of the seed meal with and without a capsule from Sacha inchi: The profile of fatty acids (Saturated; Polyunsaturated and

Monounsaturated) was determined in the Laboratory of Food Analysis AVVE S.A., located in the city of Guayaquil, Ecuador; through the liquid chromatography / PDA technique, according to the reference method MMQ-HPLC-09. All the samples were first determined fat by the gravimetric technique, by the method described by the modified AOAC 21TH 945.38F.

For the statistical processing of the data, the statistical package SPSS version 22.1 was implemented under Windows environment. For the analysis of the chemical composition, a descriptive statistic was performed, determining the mean and standard deviation.

Results and Discussion

The chemical composition of Sacha inchi with capsule (*Plukenetia volubilis*) which can be used as raw material for the elaboration of animal feed is shown in Table 1. It was observed that the DM had a difference of 3,62% related to the values reported by Baldeón, et al. (2015) performed only in the Sacha inchi shell, while the studies obtained by Velásquez et al. (2014) in the Pastaza Province of the Ecuadorian Amazon show a percentage of 97,4% of dry matter in shelled and roasted Sacha inchi almonds, similar to the samples obtained in this research from the province of Morona Santiago, belonging to the same way to the Ecuadorian Amazon.

The results of the organic matter of the Sacha inchi with capsule showed values of 85,15%, lower than those obtained by Castaño et al. (2012), in Sacha inchi seeds (91,67%) relating it to the conditions of sanitary management of the crop, age of the seed, harvest time and ecotype, essential characteristics to take advantage of the mineral fraction offered by the plant. The value obtained in this research could have been related to the fact that the seed was not in good condition and an inadequate handling from harvest to storage, resulting in a deterioration of the almond.

The protein result obtained in the Sacha inchi with capsule was 16% and 18,28% in the seed, values lower than those obtained by Gutiérrez et al., (2011) of 24,7% protein in seeds, in the same way that the results obtained by Ayala (2016) in the analyzes carried out on the almond from the city of Bogotá-Colombia, who obtained 28,52% protein, the values referred to in this work are attributed to the different types of soils and species Sacha inchi plant that exist in the Ecuadorian Amazon.

The protein values obtained in Sacha inchi (with or without capsule) may be suitable for feeding Creole pigs in the growth and final stages of fattening, since, according to FEDNA (2013), Iberian pigs require 16, 8% and 16,5% respectively, as well as other species of animals, which need to be investigated.

In this regard, Ruiz, et al. (2013) mention that the protein value and protein content of the Sacha inchi almond (*Plukenetia volubilis L*) depends largely on the efficiency of oil extraction; However, Ordoñez (2013) obtained superior results of protein in Sacha inchi cake analyzed in the residue of the oil extraction on a dry basis with a protein content of 51,23%.

Sacha inchi fiber with capsule showed values of 32,65%, lower results than those obtained by Benítez et al. (2015) in investigations carried out in the Guamuez Valley, Putumayo, Colombia, who indicated values of 77,84% of fiber for the shell of Sacha inchi. In turn, the fiber of the flour from the Sacha inchi seed presented values of 22,26%, results higher than those obtained by Cárdenas, (2015) of 7,21% in the degreased cake of Sacha inchi, from the city of the Tena-Province of Napo.

The ash contents (14,55%) found in this study were higher than those published by Betancouth (2013) in an investigation carried out with Sacha inchi cake after oil extraction, which obtained in the proximal ash analysis a percentage of 9,25 in BS, in the same way Chirinos et al. (2015) mention a result close to 9,35% in BS. The ash values obtained in this study could be related to the use of Sacha inchi with capsule and the nutrients of the soil from which this raw material was harvested.

On the other hand, when comparing the ELN content (31,74%,) of the flour of the Sacha inchi seed of this research with a study carried out by Baldeón et al. (2015), with values of 12,44% , shows data lower than those reached in this research.

The amount of EB, present in the flour of the Sacha inchi seed was 5497,33 Kcal / Kg MS^{-1}, values higher than those obtained by Muirragui, (2013) in the analysis carried out on the Sacha inchi cake, with a value of 4860 Kcal / Kg DM.

Table 2 describes the content of saturated, polyunsaturated, and monounsaturated fatty acids of the Sacha inchi seed meal with and without capsule. The fat content of the flour of the Sacha inchi seed (with and without capsule) was 33,64% and 39,70% respectively, values lower than those obtained by Tobar, (2018) of 44,62% present in the seed. In studies carried out by Alayón and Echeverri (2016) they indicated that the seed of Sacha inchi has around 48-50% oil, which for the most part contains polyunsaturated fatty acids that include 42-48% ALA and 32-37% of LA, with 12% monounsaturated.

Nutrients	**Seed without capsule**	**Seed with capsule**			
	Mean		**±EE**	**Minimum**	**Maximum**
Crude Protein, %	18,28	16,00	0,36	14,02	18,70
Crude fiber, %	22,26	32,65	0,22	22,00	33,41
ELN, %	31,74	-	0,92	31,02	32,86
EB, kcal/Kg MS^{-1}	5497,33	-	301,52	5306,00	5845,02
Dry matter, %	-	92,02			
Organic matter, %	-	85,15			
Ash, %	-	14,55			

Table 2. Fatty acid profile of sacha inchi flour with and without capsule.

Fatty acids, g/%	Sacha inchi (*Plukenetia volubilis)*	
	Seed without capsule	Seed with capsule
Fats, g/100g	39,70	33,64
Saturated	3,28	2,75
Palmitic (C16:0)	2,10	1,66
Stearic (C18:0)	1,05	0,84
Arachidic (C20:0)	0,06	0,15
Polyunsaturated	32,29	27,48
Linoleic (LA, C18:2, Omega 6)	13,40	11,42
α-Linolenic (ALA, C18:3, Omega 3)	18,89	16,06
Monounsaturated	4,13	3,41
Oleic (AO, C18:1, Omega 9)	4,13	3,41

The fatty acid analysis revealed that the concentrations of saturated fatty acids in the seed without capsule are greater than 3,28 g /%, unlike the flour with the seed that contains the capsule of 2,75 g /%, with the same behavior the polyunsaturated fatty acids of 32,29 and 27,48 g /%, the monounsaturated ones of 4,13 and 3,41 g /%, in favor of the seed without capsule versus the seed with capsule, respectively in each of the acids certain fatty. The Sacha inchi analyzed in this study, having a lower content of saturated fatty acids and a higher content of poly and monounsaturates, is much healthier for animal health, because the animal organism cannot synthesize them (Henao and Barreto, 2016).

The results obtained in general of the fatty acids in Sacha inchi with or without capsule are lower than those found by Gutiérrez et al. (2011) in Colombia, however, these raw materials are by-products of the export industry of Sacha inchi from the Amazon area of the equator and significant concentrations of Omega 6 are observed at 13,40 and 11,42 g /%; Omega 3 (18,89 and 16,06 g /%), in the seed without and with capsule respectively. In both raw materials these properties make it a great opportunity to be included in diets as sources of animal feed.

In both by-products of Sacha inchi, the predominant fatty acids are α-linolenic acid (C18: 3 ω-3) and linoleic acid (C18: 2 ω-6, a finding like those described by Ramos-Escudero et al. (2019) who observed a wide range of variations in the concentrations of oleic acid unsaturated fatty acids varied between 9 and 23%, while linoleic acid fluctuated between 21 and 53%, and α-linolenic acid varied between 10 and 55%, in Sacha inchi oil of supermarkets and the National Germplasm Bank in Lima, Peru.

The fatty acid profile in this research is closely related to the study carried out by Zuloeta, (2014) in 16 cultivars of Sacha inchi in Peru, refers to average α-linolenic acid values of 14,6 g / 100g seed, linoleic acid 13,3 g / 100g seed and of oleic acid 4,1 g / 100g seed, with lower values of saturated fatty acids (palmitic, stearic and vaccenic acid with an average of 1,9; 1,2 and 0,3 g / 100g seed, respectively), attributing differences between cultivars or varietals due to agroclimatic factors, soil characteristics, genetic and environmental factors in the development of these fruits (Cai et al. 2012 and Hurtado, 2013).

Conclusions

1. The flour of the Sacha inchi seed with and without capsule from the crops of the Huamboya canton, Morona Santiago Province, has an adequate protein for the swine species, as well as the fiber, fat and energy contents are acceptable, to be used in the elaboration of diets for creole pigs in the growth stage and final fattening.

2. Based on the results found, the flour of the Sacha inchi seed with or without capsule is an important source of polyunsaturated fatty acids, which could provide beneficial effects due to their nutritional qualities and nutritional value, to be considered in the inclusion of diets for animal feed.

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