Digestible energy and nutrient digestibility of full-fat soybean meal in adult and growing guinea pigs

Energía digestible y digestibilidad de nutrientes de la harina de soya entera en cuyes adultos y en crecimiento

Energia digestível e digestibilidade de nutrientes do farelo de soja integral em cobaias adultas e em crescimento

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Abstract

The use of full-fat soybean meal (FSBM) in feeding guinea pigs would be a good alternative to improve dietary protein, but little is known about the use of their nutrients in this animal species. This study aimed to determine the nutrient digestibility and energy digestible of FSBM and the effects of its incorporation in guinea pigs' diets. Thirty male guinea pigs were used, aged two (15 animals) and 10 weeks (15 animals). A basal diet was used, from which the weight/weight substitution was carried out at proportions of 15 and 30 % inclusion of FSBM. The digestibility of nutrients in the diets differed between ages, being higher in adults than in growing ($p<0.001$). The digestibility of DM and nutrients of FSBM was high, being higher in adult guinea pigs (76.94 % DM, 77.56 % OM, 82.34 % CP, 86.87 % EE, and 60.96 % CF) than growing (71.78 % DM, 72.35 % OM, 66.24 % CP, 60.37 % EE and 50.41 % CF) ($p<0.001$). The digestible energy was 3375 and 3093 $kcal.kg^{-1}$ DM for adult and growing guinea pigs respectively ($p<0.001$). FSBM meal is a good option for feeding growing and adult guinea pigs due to its high nutritional value and digestibility.

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Resumen

El uso de harina de soya entera (FSBM) en la alimentación de cuyes sería una buena alternativa para mejorar la proteína dietaria, pero se sabe poco sobre el uso de sus nutrientes en esta especie animal. Este estudio tuvo como objetivo determinar la digestibilidad de los nutrientes y la energía digerible de la FSBM y los efectos de su incorporación en las dietas de los cuyes. Se utilizaron treinta cuyes machos, de dos y 10 semanas de edad (15 animales/edad). Se utilizó una dieta basal, a partir de la cual se realizó la sustitución peso/peso en proporciones de 15 y 30 % de inclusión de FSBM. La digestibilidad de los nutrientes de las dietas fue diferente entre edades, siendo mayor en adultos que en crecimiento (p<0.001). La digestibilidad de la MS y los nutrientes de la FSBM fue alta, siendo mayor en cuyes adultos (76,94 % MS, 77,56 % MO, 82,34 % PB, 86,87 % EE y 60,96 % CF) que en crecimiento (71,78 % MS, 72,35 % MO, 66,24 % CP, 60,37 % EE y 50,41 % CF) (p<0,001). La energía digestible fue 3375 y 3093 kcal.kg^{-1} MS para cuyes adultos y en crecimiento respectivamente (p<0,001). La harina de FSBM es una buena opción para la alimentación de cuyes adultos y en crecimiento debido a su alto valor nutricional y digestibilidad.

Palabras clave: *Cavia porcellus*, *Glycine max*, digestibilidad, energía, valor nutricional.

Resumo

A utilização do farelo de soja integral (FSBM) na alimentação de cobaias seria uma boa alternativa para melhorar a proteína dietética, mas pouco se sabe sobre a utilização de seus nutrientes nesta espécie animal. Este estudo teve como objetivo determinar a digestibilidade dos nutrientes e a energia digestível do FSBM e os efeitos de sua incorporação nas dietas de cobaias. Foram utilizados trinta cobaias machos, com idade de duas (15 animais) e 10 semanas (15 animais). Foi utilizada dieta basal, a partir da qual foi realizada a substituição peso/peso nas proporções de 15 e 30 % de inclusão de FSBM. A digestibilidade dos nutrientes das dietas foi diferente entre as idades, sendo maior nos adultos do que em crescimento (p<0,001). A digestibilidade da MS e dos nutrientes do FSBM foi elevada, sendo maior em cobaias adultas (76,94 % MS, 77,56 % MO, 82,34 % PB, 86,87 % EE e 60,96 % FC) do que em crescimento (71,78 % MS, 72,35 % MO, 66,24 % CP, 60,37 % EE e 50,41 % CF) (p<0,001). A energia digestível foi de 3.375 e 3.093 kcal.kg^{-1} MS para cobaias adultas e em crescimento respectivamente (p<0,001). A farinha de FSBM é uma boa opção para alimentação de cobaias em crescimento e adultas devido ao seu alto valor nutricional e digestibilidade.

Palavras-chave: *Cavia porcellus*, *Glycine max*, digestibilidade, energia, valor nutricional.

Introduction

A diet meeting nutritional requirements serves as the foundation for the successful production of any animal species (Wu, 2022). Information regarding the nutritional contribution of feeds to fulfill animal nutritional requirements is crucial (Keeble, 2023), as it allows an understanding of the level of utilization of nutrients and energy. That is why the study of chemical composition and digestibility is the first step in carrying out its nutritional value (Wang *et al*., 2022). Soybean meal (SBM) is a source of protein and indispensable amino acids (Zhang *et al*., 2013) which are present in relatively low concentrations in commonly used feed grains (Degola *et al*., 2019). In addition to the above, SBM is highly digestible (Lagos & Stein, 2017), resulting in lower nitrogen excretion. Due to these benefits, is widely used in formulating diets for ruminant and non-ruminant animals, companion animals, or in aquaculture (Shen *et al*., 2015).

The nutritive value and chemical composition of SBM depend on the environmental conditions, climatic changes, seed variety, harvesting, oil extraction, storage, topography, and soil fertility (Stefanello *et al*., 2016; Degola *et al*., 2019; Ibáñez *et al*., 2020; Arjona-Smith *et al*., 2022).

Andean mountains are cultural landscapes, where *Cavia porcellus* L. is considered a cultural and natural resource to improve the quality of life and economic sustainability in the Andean communities (Patiño *et al*., 2021). The guinea pig (*Cavia porcellus*), is a rodent mammal native to South America, it is a small animal, easy to handle, with short production cycles (Patiño *et al*, 2019). The guinea pig is a non-ruminant herbivorous species with post-gastric fermentation (Karasov & Douglas, 2013; Crowley *et al*., 2017) that develops a colonic separation mechanism, with a high capacity to digest fibrous feeds and dietary protein (Wen-Shyg *et al*., 2000; Franz *et al*., 2011). The caecum occupies most of the abdominal cavity (Imam, *et al*. 2021). In guinea pigs, the colon-rectum is the primary site for fermentation (Chiou *et al*., 2000; Grant *et al*., 2014) and ferments the fiber better than other monogastric animals (Castro-Bedriñana & Chirinos-Peinado, 2021). Guinea pigs exhibit vigorous coprophagy; its physiological significance lies in the use of bacterial proteins and vitamins B or K synthesized by microorganisms in the large intestine; this coprophagy changes according to nutritional requirements, such as growth, reproduction, or aging (Ebino, 1993).

It is important to know the nutritional value of feeds, to formulate economically viable diets and achieve high yields, which requires determining their energy content, availability of nutrients, and chemical composition (Castro-Bedriñana & Chirinos-Peinado, 2021). On the other hand, the productivity of guinea pigs can be increased, among other things, by improving their diet and, above all, by providing them with a balanced feed ration (Wauffo *et al*., 2020) using ingredients such as soybean meal. However, there is very little information on its level of use in this animal species. This study aimed to determine the digestible nutrients and energy of full-fat soybean meal and the effect of its variation in incorporation levels in the diet of guinea pigs.

Materials and methods

The study was conducted at a guinea pig production farm and the Laboratory of Animal Nutrition of the Universidad Nacional de San Antonio Abad del Cusco (Peru), situated at an altitude of 3230 above sea level.

Animals and housing

Thirty improved type I guinea pig males (Perú breed) were used, with an average age of two (15 animals) and 10 weeks (15 animals) with a weight of 318.6 ± 33.6 g and 822.7 ± 68.0 g, respectively. Individual metabolic cages (0.50 m × 0.25 m × 0.40 m) with manual feeders, automatic drinkers, and feces collectors were used. The animals remained there for 21 days, 10 days for acclimation (new husbandry conditions and feeding), and 11 days for evaluation (experimental phase). The environmental conditions were controlled (average temperature 20 °C and humidity 60 %). The lighting was artificial (24 hours) every day.

Treatments, feed, and water supply

A basal diet was used (table 1), from which the weight/weight percentage substitution was made in proportions of 15 % and 30 % inclusion of full-fat soybean meal (FSBM). The FSBM used was the one available on the market, and no additional treatment was done for its use, because the objective was to value the ingredient as it is available on the market.

Table 1. The basal diet used in the study and their nutritional composition.

Ingredients	Inclusion level (%)
Corn	10.00
Barley	31.02
Alfalfa meal	12.38
Soybean meal (44 % CP)	11.68
Wheat by-product	32.31
Soybean oil	0.36
Calcium carbonate	0.89
Dicalcium phosphate	0.82
Salt	0.24
Dl-Methionine	0.03
L- Lysine	0.03
Sodium bicarbonate	0.15
Mineral-vitamin premix*	0.10
Calculated composition (as-fed)	
Digestible energy, $Mcal.kg^{-1}$	2.80
Crude protein, %	16.80
Ether extract, %	2.80
Crude fiber, %	9.44
Nitrogen-free extract, %	55.08
Ash, %	5.31
Lysine, %	0.80
Methionine, %	0.28
Methionine + cystine, %	0.58
Calcium, %	0.80
Available phosphorous, %	0.33

*Vitamin-mineral premix supplied (per kilogram): Retinol 12,000 IU, Cholecalciferol 5,000 IU, DL α-tocopherol acetate 30 IU, Menadione bisulfate 3 mg, Thiamin 2 mg, Riboflavin 10 mg, Pyridoxine 3 mg, Cyanocobalamin 0.015 mg, Pantothenic acid, 11 mg, Folic acid 2 mg, Niacin 30 mg.

The analysis of the diets and FSBM is shown in table 2. Where the treatments (T1, T2, and T3) correspond to the diets (basal, 15 %, and 30 % of substitution), with five repetitions (guinea pigs) in both ages (growing and adult).

Guinea pigs were fed once a day (9:00 am) and had free access to water (automatic drinkers). All diets were provided as a mash, and the amount of feed supplied each day and any feed refusal (*ad libitum* feeding) were recorded (it was > 20 %).

Sample collections and laboratory analysis

The feces were cleaned, weighed, and stored in plastic bags and frozen (-20 °C) for later analysis. A balance (Sartorius, Germany) with a capacity of 2.000 ± 0.01 g was used to weigh the feeds, feces, and animals.

Table 2. Chemical composition of experimental diets and full-fat soybean meal.

Components (%)	T1	T2	T3	FSBM
Total (As fed)	100	100	100	100
Basal diet	100	85	70	-
Full-fat soybean meal	-	15	30	-
Diet and ingredient analysis (DM)				
Organic matter	92.39	92.45	92.54	93.59
Crude protein	14.98	21.81	24.63	39.74
Ash	7.61	7.55	7.46	6.41
Ether extract	3.86	6.16	8.53	21.78
Crude fiber	14.89	13.55	12.96	7.05
NDF	30.09	27.84	26.77	-
ADF	19.04	17.80	17.74	-
GE, $kcal.kg^{-1}$	4363	4538	5050	6676

Abbreviations: DM: Dry matter; GE: gross energy; FSBM: full-fat soybean meal, NDF: neutral detergent fiber, ADF: acid detergent fiber.

The samples (feed and feces) were dried at 60 °C (48 hours), in a forced air circulation oven (FED 720®, Binder GmbH, Tuttlingen, Germany) and ground (1mm screen, Mill in MF10-BASIC, IKA). Dry matter was determined in a forced air circulation oven (FED 720, Binder) at 105 °C for 16 h (method 950.46B AOAC, 2006). Ash by incineration samples in a muffle furnace (ECO110/9®, Protherm, Ankara, Turkey) at 600 °C for 8 h (method 942.05 AOAC, 2006). Nitrogen using an elemental analyzer (2400 series II®, PerkinElmer) (method 990.03 AOAC 2007). Crude fiber (method 978.10 AOAC, 2006), neutral detergent fiber, and acid detergent fiber were determined using an automated fiber analysis (FIBRETHERM®, Gerhardt, Germany). Ether extract using an automatic crude fat analyzer (SOX 606®, Hanon, China) (method 920.39 AOAC 2006). The gross energy was analyzed using an automatic bomb calorimeter (6400 Calorimeter, Parr, USA). Samples were weighed on an analytical balance (200 ± 0.01 g, Quintix 224-1X, Sartorius, Germany) and an ultra-microbalance (5 g ± 0.1 µg, AD 6000, Perkin Elmer, USA).

Apparent digestibility

To determine the apparent digestibility (Da) in the diets, the direct method was used (Castro-Bedriñana & Chirinos-Peinado, 2021): Da (%) = [(NC (g) - NH (g)) / (NC (g)] x 100, were NC: Nutrient consumed, NH: Nutrients excreted in feces (Díaz Céspedes *et al*., 2021). The Da of FSBM (DAs) was determined using the substitution method and total fecal collection, accounting for the apparent digestibility of basal diet (BD) and experimental diets (EpD): DAa (%) = (100 (EpD - BD)) / S + BD, were EpD: apparent digestibility of experimental diets, BD: apparent digestibility of basal diet, S: FSBM substitution level (Baker *et al*., 2014; Díaz Céspedes *et al*., 2021).

Digestible energy

Apparent digestible energy (EDa) was expressed on a dry basis: EDa ($kcal.kg^{-1}$) = GE - (EH x Qh) / Qa, where GE: gross feed energy ($kcal.kg^{-1}$), EH: gross energy of feces ($kcal.kg^{-1}$), Qh: amount of feces produced per day (kg), and Qa: amount of feed consumed per day (kg) (Díaz Céspedes *et al*., 2021).

Statistical analysis

Firstly, the normal distribution (Anderson and Darling tests) and homogeneity of variance (Levene's test) were verified. The data were analyzed using a factorial ANOVA that included the level of inclusion of FSBM (0, 15, and 30 %), age groups (growing and adult), and their interaction. Differences among treatments means were determined by Tukey's multiple range test. A p-value < 0.05 was considered statistically significant. Each guinea pig was treated as the experimental unit. A correlation analysis was performed between the nutritional composition of the diets with the feed intake and digestibility.

Results and discussion

Feed intake and apparent digestibility in diets

Table 3 shows the values of intake, feces, and digestibility of guinea pigs fed increasing levels of FSBM. There was an interaction among ages and treatment for consumption of DM, OM, CP, EE, gross energy ($p<0.05$), and excretion of CP ($p<0.01$), while for digestibility there was interaction in CP, and EE ($p<0.01$).

Dry matter intake (DMI) was higher in the adult guinea pigs (45.9 ± 12.4 $g.d^{-1}$) than in growing ones (21.0 ± 3.85 $g.d^{-1}$) ($p<0.01$), and differed between treatments and the interaction between age groups and level of inclusion of FSBM ($p<0.05$), where the highest DMI was observed with 15 and 30 % of FSBM in the adult guinea pigs. The increase in the level of FSBM improved DMI in adult guinea pigs, but in growing guinea pigs, the highest inclusion reduced DMI ($p<0.03$), the same result was observed with the intake of organic matter. Likewise, differences were observed in the intake of crude protein, and ether extract, between age, treatment, and their interaction ($p<0.01$) where adult guinea pigs with 30 % of FSBM inclusion had the highest intake ($p<0.01$).

On the other hand, crude fiber intake was different between ages ($p<0.01$) and was higher for adults than growing guinea pigs ($p<0.01$; 6.31 vs 2.86 $g.d^{-1}$), but no significant differences were found between treatments and their interaction ($p>0.05$). Energy intake differed between ages, treatments, and interactions ($p<0.01$). Energy consumption was higher in adult guinea pigs with 30 % inclusion of FSBM than in the other treatments, and in all cases, this consumption was higher in adult guinea pigs compared to growing animals (214.14 vs 97.53 $kcal.d^{-1}$).

Voluntary feed intake is influenced by both animal and feed factors (Riaz *et al*., 2014) hence the productivity of guinea pigs can be improved, above all, by providing a well-balanced ration (Wauffo *et al*., 2020). In this case, the observed variation in feed intake and nutrient levels would be related to the nutritional content of the diets. Nutrient intake in mammalian herbivores is dependent on the energy density of the diets, quantity, and nutritional composition of the plant species and plant parts they consume (Castro-Bedriñana & Chirinos-Peinado, 2021). It has long been suggested that the capacity of the digestive tract is an important limiting factor in feeding; this seems to be especially true for ruminants, in which fermenting bulky feed remains in the rumen for very long periods (Forbes, 2007). T1 and T2 had the highest levels of fiber (14.89 % and 13.55 % respectively), which would have determined greater cecal retention. In guinea pigs increased cecal retention time limits their ability to increase feed intake and recover soluble nutrients on poorly digestible high-fiber diets (Stevens and Hume, 1998), thereby limiting the feed intake of dry matter and nutrients, since an inverse relationship exists between the level of dietary fiber (CF, FDN, and FDA) and the feed intake of dry matter ($R^2 = 0.846$).

If nutrient requirements increase in proportion to metabolic requirements, and feed intake is restricted directly by gut capacity, small herbivores must consume highly concentrated diets of nutrients (Karasov & Douglas, 2013), as observed in the present study, where the highest consumption was with the T3, which had the lowest fiber content in the diet (12.96 %), on similar way, voluntary feed intake in the pig, is affected by dietary factors, were the pig adjust the feed intake to maintain its energy requirement, although the level of energy intake slightly declines as energy concentration decreases, due a progressive limitation of gastrointestinal capacity before energy demand is met, as diet bulkiness becomes more important (Henry, 1985). However, control of feed intake is complex and even if this perspective were correct, multiple factors (energy concentration, protein level and amino acid balance, etc) can compromise the appropriate adjustment in feed intake (Classen, 2017).

The dry and organic matter content in the feces differed between ages ($p<0.05$), being higher in adults than in growing guinea pigs (7.90 vs 4.88 $g.d^{-1}$); but no significant differences were found between treatments and the interaction of age by treatment ($p>0.05$). For crude protein content in feces, significant differences were found for the age-by-treatment interaction ($p<0.01$), where the excretion was higher in adults than in growing in the three treatments.

The excretion of EE, and CF, had differences either between ages and treatments ($p<0.01$), no significant differences were found between the interaction of age by treatment ($p>0.05$). The highest excretion (EE and CF) was in adults ($p<0.01$). When evaluating the level of inclusion of FSBM, the excretion of EE was greater at 30 % than with other treatments ($p<0.01$), and the excretion of CF was higher at 15 and 30 % ($p<0.01$). The energy excretion was higher in adults than in growing ($p<0.01$), no significant differences were found between treatment and, the interaction of age by treatment ($p>0.05$).

Differences were observed in the digestibility of DM, OM, CP, EE, CF, and energy between ages ($p<0.01$), being greater in adults compared to growing guinea pigs. The greatest difference observed was for EE (19 %), CP, and CF (10 %) in the other nutrients this difference was small. As indicated above, the interaction effect for CP and EE digestibility was greater in adults with 15 and 30 % FSBM ($p<0.01$) than in others. Regarding the treatments, significant differences were observed for the digestibility of DM, CP, EE, CF, and energy ($p<0.01$), and in all cases, the digestibility was higher in treatments T3 and T2 than in T1. Digestible energy (DE), was different between ages and treatments but no difference was observed in the interactions ($p<0.01$), being greater in adults (3,782.95 $kcal.kg^{-1}$ DM) than in growing (3,479.10 $kcal.kg^{-1}$ DM) ($p<0.01$). With the treatments, the ED was high with the T3 compared to the other treatments ($p<0.01$).

As a general rule, digestive efficiency declines with an increasing amount of refractory material in feed (Karasov & Douglas, 2013). The feed of the guinea pigs contains very variable amounts of protein, fiber, fat, and energy, and the majority is fibrous nature. Feeds rich in fiber (insoluble fiber) and ash are associated with less utilization of nutrients and energy (Cheeke *et al*., 2020), while feeds rich in raw protein (different levels of protein) and energy are associated with greater utilization (digestibility) of nutrients and energy (Castro-Bedriñana & Chirinos-Peinado, 2021; Farías-kovac *et al*., 2020). This effect was observed in the study where the digestibility of nutrients and energy was lower with the higher level of crude fiber, NDF, ADF, and ash, but it was high with increasing level of protein showing a high correlation between the level of dietary protein and digestibility ($R^2 = 0.842$).

Table 3. Feed intake and apparent digestibility with the inclusion of FSBM in growing and adult guinea pigs (dry matter basis).

Diets	Growing			Adult			SEM	*p*-value		
	T1	T2	T3	T1	T2	T3		Treat-ment	Age	T × A
Feed intake (g.day^{-1})										
Dry matter	19.97^{cB}	22.69^{cB}	20.29^{cB}	42.72^{bA}	45.20^{aA}	49.68^{aA}	4.17	0.034	0.001	0.029
Organic matter	18.45^{cB}	20.98^{cB}	18.78^{cB}	39.47^{bA}	41.79^{aA}	45.98^{aA}	1.97	0.031	0.001	0.028
Crude protein	2.99^{eB}	4.95^{dB}	4.99^{dB}	6.40^{cA}	9.86^{bA}	12.24^{aA}	0.51	0.001	0.001	0.001
Ether extract	0.79^{dB}	1.36^{dB}	1.73^{cB}	1.65^{cA}	2.78^{bA}	4.24^{aA}	0.21	0.001	0.001	0.001
Crude fiber	2.99^{B}	2.91^{B}	2.70^{B}	6.36^{A}	6.12^{A}	6.52^{A}	0.47	0.671	0.001	0.570
Energy (kcal.d^{-1})	87.15^{cB}	102.99^{cB}	102.45^{cB}	186.40^{bA}	205.12^{bA}	250.89^{aA}	1.50	0.001	0.001	0.001
Excreted feces (g.day^{-1})										
Dry matter	5.68^{B}	4.90^{B}	4.93^{B}	9.67^{A}	7.91^{A}	9.06^{A}	0.58	0.107	0.001	0.466
Organic matter	5.15^{B}	4.45^{B}	4.49^{B}	8.69^{A}	7.03^{A}	7.97^{A}	0.60	0.062	0.001	0.370
Crude protein	1.03^{bB}	0.83^{bB}	0.84^{bB}	1.12^{abA}	1.12^{abA}	1.36^{aA}	0.05	0.208	0.231	0.005
Ether extract	0.31^{bA}	0.29^{bA}	0.35^{aA}	0.22^{bB}	0.21^{bB}	0.29^{aB}	0.02	0.001	0.001	0.874
Crude fiber	1.53^{aB}	1.21^{bB}	1.14^{bB}	2.48^{aA}	1.82^{bA}	2.12^{bA}	0.15	0.001	0.001	0.159
Energy (kcal.d^{-1})	26.22^{B}	24.39^{B}	23.46^{B}	42.14^{A}	34.97^{A}	40.26^{A}	0.55	0.001	0.132	0.335
Apparent digestibility (%)										
Dry matter	71.54^{bB}	77.24^{aB}	75.61^{aB}	76.65^{bA}	83.42^{aA}	80.95^{aA}	1.04	0.001	0.002	0.742
Organic matter	72.12^{B}	77.65^{B}	75.96^{B}	77.25^{A}	84.09^{A}	81.89^{A}	0.60	0.062	0.001	0.367
Crude protein	65.45^{cB}	82.38^{bB}	83.22^{bB}	81.99^{bA}	84.27^{aA}	88.42^{aA}	0.53	0.001	0.001	0.001
Ether extract	60.23^{eB}	73.48^{dB}	79.45^{cB}	86.01^{bA}	92.64^{aA}	92.82^{aA}	0.13	0.001	0.001	0.001
Crude fiber	47.96^{bB}	58.43^{aB}	55.84^{aB}	59.08^{bA}	70.15^{aA}	66.65^{aA}	0.57	0.001	0.001	0.166
Energy	70.04^{bB}	76.53^{aB}	77.02^{aB}	76.63^{bA}	83.87^{aA}	83.16^{aA}	0.61	0.001	0.001	0.892
Digestible energy										
Kcal.kg^{-1} MS	3,065.32^{cB}	3,482.50^{bB}	3,889.49^{aB}	3,343.33^{cA}	3,806.23^{bA}	4,119.28^{aA}	33.79	0.001	0.001	0.924

^{a,b,c}Lowercase letters indicate differences between treatments within each age group (p<0.05). ^{A,B}Uppercase letters indicate differences between age groups (p<0.05). SEM: Standard error of the mean.

Although the digestibility of the fiber was indeed lower compared to the other nutrients, the values were high when compared to rabbits and rats. So, the guinea pig is more efficient than the rabbit in digesting the crude fiber and digests the organic matter and crude fiber as efficiently as horses and ponies (Slade & Hintz, 1969). This is possible due to the relatively longer length of the large intestine in guinea pigs, which is the major site for fermentation (Chiou *et al*., 2000), and the caecum occupies most of the abdominal cavity (Imam, *et al*. 2021).

Additionally, the guinea pig exhibited vigorous coprophagy (Ebino, 1993) with a colonic separation mechanism (Wen-Shyg *et al*., 2000) and slower, potentially less complete removal of bacteria from the digestion plug in a larger colon. The vigorous coprophagy, have a physiological significance lies in the use of bacterial proteins and vitamins B or K synthesized by microorganisms in the large intestine (Ebino, 1993). It probably also explains the higher digestibility of fiber from the same feed in guinea pigs and other herbivorous rodents as compared with rabbits (Franz *et al*., 2011).

Digestibility of nutrients and digestible energy of full-fat soybean meal

The digestibility of DM, OM, and the nutrients of the FSBM, is shown in table 4. It is observed that the digestibility values are higher in adults for all nutrients than in growing guinea pigs (p<0.01). Also, it is seen that the digestibility values are lower than 70 % for CP, EE, and CF in growing guinea pigs, and for adults, these values are low in crude fiber (60.92 %). The digestible energy of FSBM meal was different between adults and growing guinea pigs (p<0.01), this value was 3,375 kcal.kg^{-1} DM for adults and 3,093 kcal.kg^{-1} DM for growing guinea pigs, where the digestibility was higher for adults (50.56 %) than in growing guinea pigs (46.33 %) (p<0.01).

Table 4. Digestibility of the nutrients and energy digestible to full-fat soybean meal in growing and adult guinea pigs (dry basis).

Ingredient	Growing	Adult	SEM	p-Value
Digestibility, %				
Dry matter	72^{b}	77^{a}	0.607	0.001
Organic matter	72^{b}	78^{a}	0.613	0.001
Crude protein	66^{b}	82^{a}	1.89	0.001
Ether extract	60^{b}	87^{a}	3.12	0.001
Crude fiber	50^{b}	61^{a}	1.24	0.001
DE, kcal.kg^{-1} MS	3,093^{b}	3,375^{a}	33.2	0.001
Digestibility, %	46^{b}	51^{a}	0.497	0.001

^{A,B}Letters indicate differences (p<0.01). SEM: Standard error of the mean.

Nutrient digestibility of FSBM was lower than in diets, especially in fiber, which could be attributed to the fact that raw soybeans have anti-nutritional quality factors (Colombino *et al*., 2023), which influence the utilization of its nutrients mainly in growing guinea pigs. The digestibility of non-starch polysaccharides is affected by a multitude of factors, including animal species, age groups of animals, solubility, chemical structure, and their quantity in the diet (Valentine *et al*., 2017).

In this case, the age of the guinea pigs had a marked effect on the digestibility of nutrients and energy in the diets and FSBM, determining that the values of digestible energy were higher for adult guinea pigs than in growing, attributable to the differences in their physiological development of the gastrointestinal tract. Therefore, the digestive capacity, enzymatic production, and fermentation capacity would not have been sufficient to achieve the best use of nutrients and energy (Fernández *et al*., 1986; Sciellour *et al*., 2018). Similar effects were observed in pigs, where digestibility of NSP increases with the age of animals since grower and finisher pigs can utilize dietary fiber better than young piglets (Sciellour *et al*., 2018).

Conclusions

The digestibility of dry matter and nutrients in full-fat soybean meal are high, exhibiting greater values in adults than in growing. The inclusion level of full-fat soybean meal in the diets affected the digestibility of nutrients, being higher with high levels, associated with the high crude protein, and fat content and lower fiber. The digestible energy of full-fat soybeans was different between the ages, being 3,093 and 3,375 kcal.kg^{-1} DM, with 46 % and 51 % of digestibility for growing and adult guinea pigs respectively.

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