Revista Brasileira de Ciência Avícola
ISSN: 1516-635X
revista@facta.org.br
Fundação APINCO de Ciência e Tecnologia Avícolas
Brasil

Moraes, ML de; Ribeiro, AML; Kessler, A de M; Cortés, MM; Ledur, VS; Cura, E

Comparison of the effects of semi-refined rice oil and soybean oil on meat oxidative stability, carcass yield, metabolism, and performance of broilers

Revista Brasileira de Ciência Avícola, vol. 11, núm. 3, julio-septiembre, 2009, pp. 161-167
Fundação APINCO de Ciência e Tecnologia Avícolas
Campinas, SP, Brasil

Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X Jul - Sep 2009 / v.11 / n.3 / 161 - 167

Comparison of The Effects of Semi-Refined Rice Oil and Soybean Oil on Meat Oxidative Stability, Carcass Yield, Metabolism, and Performance of Broilers

■ Author(s)

Moraes ML de
Ribeiro AML
Kessler A de M
Cortés MM
Ledur VS
Cura E

Departamento de Zootecnia
Universidade Federal do Rio Grande do Sul

■ Mail Address

Mariana Lemos de Moraes
Av. Bento Gonçalves, 7712
91.540-000. Porto Alegre, RS, Brasil

E-mail: marimoraes@brturbo.com.br

■ Keywords

Broiler, carcass, metabolism, rice oil, soybean oil, performance.

Arrived: May/2009
Approved: July/2009

ABSTRACT

Two experiments (EXP 1 and EXP 2) were conducted to compare soybean oil (SO) and semi-refined rice oil (RBO) added to broilers diets. In EXP 1, 400 male Ross x Ross 308 broilers were reared in battery cages, and their performance was evaluated. A metabolism assay was performed. In EXP 2, 1344 broilers from the same strain were reared in floor pens with rice husks litter. In addition to performance, carcass yield and meat oxidative stability were evaluated. In both EXP, birds were distributed in a 2x4 factorial arrangement, with two types of oils (SO or RBO) and four oil inclusion levels (1%, 2.5%, 4%, or 5.5%). Two periods were considered: starter (1 to 21 days of age) and grower (22 to 42 days). In both EXP, oil type had no influence on starter performance. Although treatments promoted similar in weight gain (WG) and feed intake (FI), grower birds fed RBO had better feed conversion (FCR) in EXP 2, but not in EXP1. In both trials, increasing dietary oil levels negatively influenced FI and positively FCR. Weight gain was similar among all treatments in EXP 1, whereas in EXP 2, WG was higher when 4 and 5.5% oil was included in the feed. RBO presented 94% fat metabolizability, and crude energy and metabolizable energy levels of 9.260 and 8.714 kcal/kg, respectively. Carcass yield was not influenced by oil type; however, oil inclusion level negatively affected breast yield. The experimental treatments had no effect on meat oxidative stability. RBO can be used as an alternative to soybean oil in broilers diets.

INTRODUCTION

The inclusion of oil in broiler diets increases dietary energy density, improves feed palatability, reduces feed dust, and improves feed conversion ratio (Lara *et al*., 2005) and weight gain (Raber *et al*., 2008).

Soybean oil is the most commonly included oil in broiler feeds, but other oils can also be used as energy source, such as rice oil. In addition of having higher levels of tocopherols, tocotrienols, and phytosterols, which are responsible for higher resistance to oxidation and spoilage (Paucar-Menacho *et al*., 2007), as compared to soybean oil, another possible advantage is that it contains gamma-orizanol, a complex blend of ferulic acid with phytosterols and tripternic alcohols (Souza *et al*., 2005). Due to its antioxidant action (Juliano *et al*., 2005), gamma-orizanol is applied in anti-aging therapies. In humans with excessive cholesterol blood levels, rice oil reduced total cholesterol levels and LDL/HDL ratios (Berger *et al*., 2005; Scavariello *et al*., 1998). This effect was also observed in hamsters (Wilson *et al*., 2007). Although several studies show the action of rice oil against cardiovascular disorders, the compounds responsible for cholesterol reduction and their modes of action are not precisely known yet.

Gobesso *et al*. (2007) observed that stallions fed semi-refined rice oil rich in gamma-orizanol had better body condition score and higher weight gain as compared to those fed soybean oil. According to the study of Fry *et al*. (1997) in humans, the gamma-orizanol complex is capable of increasing lean muscle mass, improving recovery after exercises, and reducing body fat, and therefore it is a natural alternative to anabolic steroids.

As to fatty acid composition, soybean oil contains more linoleic and linolenic acid, whereas rice oil contains more oleic acid, being richer in monounsaturated fatty acids.

Many studies were performed with gamma-orizanol, but no results have been yet reported relative to the performance of broilers fed rice oil. In the present study, two experiments were carried out to evaluate the potential replacement of soybean oil with semi-refined rice oil using performance, metabolism, meat oxidative stability, and carcass yield responses of broilers fed different levels of soybean soapstock or semi-refined rice oil.

MATERIAL AND METHODS

Two experiments were carried out

In the first trial (EXP 1), 400 one-day-old male Ross 308 chicks were housed in battery cages in an environmentally-controlled room maintained at thermal-comfort temperatures. Each cage, measuring 0.72m^2, housed 10 birds. At 21 days of age, birds were transferred to 0.84-m^2 cages, and at 28 days, two birds per cage were randomly removed to allow adequate space for bird development.

In the second trial (EXP 2), 1344 one-day-old chicks of the same genetic strain were housed in an experimental poultry house divided into 48 floor pens with rice husks litter, containing 28 birds each, and equipped with a drinker, a tube feeder.

In both trials, feed and water were offered ad libitum, and lights remained on 24 hours per day.

Two types of oil (semi-refined rice oil, soybean soapstock) were compared at four dietary inclusion levels (1%, 2.5%, 4%, 5.5%) in two different diets (starter – 1 to 21 days of age; and grower – 22 to 42 days of age). Diets were formulated to contain the nutritional levels recommended by the Brazilian Tables for Poultry and Swine (Tabelas Brasileiras para Aves e Suínos, 2005). Diets contained equal protein levels, and were different only as to the level of added oil, i.e., contained different energy levels. All birds were fed the same basal diets, which varied only as to oil type and level. When formulating the basal diet, a metabolizable energy value of 8790kcal/kg was used for both oils (Tabelas Brasileiras para Aves e Suínos, 2005).

Bird weight and feed intake were weekly determined

During EXP 1, when birds were 26 to 29 days of age, a metabolism assay was carried out in the same facilities using the method of total excreta collection, with pre-fasting and post-feeding periods of six hours. Excreta samples were dried in a forced-ventilation oven at 60^{o}C for at least 72 hours, and subsequently ground. Feeds and excreta were analyzed according to the AOAC (1993) procedures for the determination of crude fat and dry matter contents. These values were used to calculate the coefficients of metabolizability of the added fats (CMAF), as well their metabolizable energy content (MEAF), according to the method described by Henn *et al*. (2004).

In EXP 2, at day 42, two birds/pen, representing the average weight of each experimental unit, were sacrificed to determine carcass yield and the yield of selected cuts (breast, thighs, legs). Samples of the thighs of each bird were collected and submitted to the Animal Product Analysis Laboratory of the Federal University of Rio Grande do Sul (UFRGS), Brazil.

Birds were distributed in a completely randomized experimental design in a 2 x 4 factorial arrangement, i.e., two types of oil and four inclusion levels. Five and six replicates per treatment were used in EXP 1 and 2, respectively.

In both experiments, weight gain (WG), feed intake (FI), feed conversion ratio (FCR), mortality, and biological efficiency – understood as the comparison of performance curves of birds fed graded levels of each oil, were analyzed. In EXP 1, metabolism responses were applied to the Lucas test (Van Soest, 1994) in order to calculate the coefficient of metabolizability of rice oil fat. The response was obtained using analysis of regression, with the percentage of fat added to the diet as independent variable (X) and the coefficient of metabolizability of the crude fat in the corresponding diet as dependent variable (Y). Slope corresponded to rice oil metabolizability (M_{RBO}).

Rice oil metabolizable energy (ME) was calculated according to the following formula: $ME_{RBO} = M_{RBO} * GE_{RBO}$, where M is the coefficient of metabolizability of the oil, and GE is the gross energy of the oil, obtained in a calorimetric bomb.

The obtained data were submitted to analysis of variances and means were compared by the LSMean test, using the GLM module of SAS (1985) statistical package. Oil levels relative to oil types were submitted to analysis of regression using the slope-ratio technique, allowing the interpretation of the biological efficiency of the semi-refined rice oil in replacement of soybean oil.

Table 1. Ingredient and nutritional compositions of the diets supplied in the starter and grower phase in the two experiments comparing rice bran and soybean oils.

	Experiment 1		Experiment 2	
Ingredients (%)	**Starter**	**Grower**	**Starter**	**Grower**
Corn	49.9	52.5	53.53	56.86
Soybean meal	40.1	37.7	36.71	33.56
Dicalcium phosphate	1.88	1.90	1.71	1.58
Limestone	1.21	1.17	1.34	1.30
Vitamin[2]/Mineral[3] premix	0.5	0.5	0.15	0.15
Salt	0.46	0.46	0.46	0.46
DL-Methionine, %	0.26	0.19	0.29	0.25
Lysine-HCl, %	0.12	-	0.22	0.23
Choline, Cl, %	0.04	0.03	0.04	0.03
Anticoccidial	-	-	0.05	0.05
[4]Antioxidant	-	-	0.02	0.02
[1]Oil				
[1]Kaolin				
Nutrients (%)	**Starter**	**Grower**	**Starter**	**Grower**
Crude protein	21.0	20.0	21.00	20.0
Calcium	0.97	0.95	0.95	0.9
Available phosphorus	0.45	0.45	0.45	0.42
Sodium	0.20	0.20	0.20	0.20
Digestible lysine	1.1	0.95	1.16	1.10
Digestible methionine+cystine	0.84	0.75	0.84	0.78
Digestible methionine	0.54	0.49	0.54	0.49

[1] Kaolin was replaced with rice oil or soybean oil up to the percentages proposed in the treatments. The level of gamma-orizanol present in rice oil was 0.82% in both experiments. [2] Vitamin supplement (content per kg feed): Vit A 10,000 IU; Vit D3 3,000 IU; Vit E 60mg; Vit K3 3mg; Vit B1 3mg; Vit. B2 8mg; Vit B6 4mg; Vit B12 0.014mg; Pantothenic acid 20mg; Niacin 50mg; Folic acid 2mg; Biotin 0.15mg. [3] Mineral supplement (content per kg feed): Fe 40mg; Zn 80mg; Mn 80mg; Cu 10mg; I 0.7mg; Se 0.3mg. [4]Ethoxiquin.

Table 2. Metabolizable energy levels of the starter and grower diets used in the two experiments comparing rice oil to soybean oil.

	Experiment 1		Experiment 2	
Oil inclusion level	**Starter**	**Grower**	**Starter**	**Grower**
1%	2704	2731	2755	2796
2.5%	2836	2863	2887	2928
4%	2968	2995	3019	3060
5.5%	3100	3127	3150	3192

RESULTS AND DISCUSSION

In EXP 1, there was no significant interaction between oil type and inclusion levels for the evaluated parameters. Therefore, only the main effects will be discussed.

In the starter, grower, and total experimental period, rice oil and soybean oil promoted similar bird performance.

As to oil inclusion levels (1 to 5.5%), independently from oil type, increasing oil inclusion had a negative effect on feed intake and a positive effect on feed conversion ratio. This result was expected, as feeds were formulated to have increasing levels of metabolizable energy as a function of the higher levels of added fat. Responses observed in the grower period were very similar to those in the starter period (Table 3).

Also in EXP 2, no interaction was found between oil type and inclusion levels for the evaluated parameters.

In the starter period, oil type did not significantly influenced performance. However, in the grower period, despite presenting similar WG and FI, birds fed semi-refined rice oil had better FCR ($p<0.06$).

Increasing inclusion oil levels, independent of type, promoted lower FI, higher WG, and consequently better FCR both in the starter and in the grower periods (Table 4).

As other warm-blooded animals, birds ingest feed to supply their energy needs and to maintain their body temperature. Therefore, it is expected, when dietary energy increases, that animals decrease their feed intake (NRC, 1994), as shown in both present experiments. However, when the trials were compared, in EXP 1, higher dietary energy levels reduced FI, but did not affect BW or WG, whereas in EXP 2, the higher energy, in addition to reducing FI, improved WG and BW. The responses of WG increase and FCR improvement associated with dietary fat supplementation may be attributed to the extra-caloric effect of fat, which results in better energy efficiency due to the increase in dietary net energy. However, when only FCR improves and there is no increase in WG, as observed in EXP 1, there is only a mathematical advantage, as FCR always improves when FI is reduced at the same weight gain. In this case, price per kg feed would be essential to define if it is worthwhile to supply higher energy feeds, although Leeson & Summers (1997) and Sakomura *et al.* (2004) state that, despite the small performance effects, there may subtler changes in fat composition.

Other factors, in addition to dietary energy, may influence feed intake, such as bird density, feeder availability, environmental temperature, and genetic strain.

According to Leeson & Summers (1997), one of the most remarkable traits of modern broiler strains is their

Table 3. Body weight (kg), feed intake (kg), weight gain (kg), and feed conversion ratio of broilers fed diets containing rice oil or soybean oil in 1 to 5.5 inclusion levels (EXP 1).

	1 to 21 days				22 to 42 days				1 to 42 days		
	BW21	FI	WG	FCR	BW42	FI	WG	FCR	FI	WG	FCR
Oil type											
Rice	0.866	1.143	0.823	1.390	2.631	3.492	1.765	1.984	4.556	2.588	1.763
Soybeans	0.868	1.149	0.825	1.393	2.593	3.453	1.725	2.022	4.518	2.550	1.773
p	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Level of dietary oil inclusion (%)											
1.0	0.868	1.189	0.825	1.441	2.576	3.542[a]	1.709	2.075[a]	4.644[a]	2.534	1.834[c]
2.5	0.858	1.132	0.815	1.390	2.600	3.487[ab]	1.742	2.003[b]	4.540[b]	2.557	1.776[b]
4.0	0.867	1.161	0.825	1.407	2.625	3.446[b]	1.758	1.961[b]	4.522[b]	2.583	1.752[b]
5.5	0.875	1.104	0.832	1.329	2.645	3.415[b]	1.771	1.973[b]	4.443[b]	2.603	1.711[a]
p	Ns	0.01	Ns	0.0005	Ns	0.05	Ns	0.01	0.01	Ns	0.0001
CV	4.2	4.6	4.4	3.9	3.0	2.9	4.0	3.7	2.5	3.0	2.4

Means followed by different letters are significantly different (P<0.05). BW=body weight; FI=feed intake; WG=weight gain; FCR=feed conversion ratio.

Table 4. Body weight (BW, kg), feed intake (FI, kg), weight gain (WG, kg), and feed conversion ratio (FCR) of broilers fed diets containing rice oil or soybean oil in 1 to 5.5 inclusion levels (EXP 2).

	1 to 21 days				22 to 42 days				1 to 42 days		
	BW21	FI	WG	FCR	BW42	FI	WG	FCR	FI	WG	FCR
Oil type											
Rice	1.012	1.385	0.965	1.436	2.973	3.956	1.962	2.020[a]	5.314	2.927	1.818
SB	1.021	1.387	0.974	1.426	2.960	3.968	1.942	2.044[b]	5.323	2.916	1.827
p	Ns	Ns	Ns	Ns	Ns	Ns	Ns	0.06	Ns	Ns	Ns
Level of dietary oil inclusion (%)											
1.0	0.989[c]	1.437[a]	0.943[c]	1.524[a]	2.866[b]	4.036[a]	1.865[b]	2.164[a]	5.440[a]	2.808[b]	1.938[a]
2.5	1.007[bc]	1.396[ab]	0.960[bc]	1.454[b]	2.971[a]	4.013[a]	1.969[a]	2.038[b]	5.381[a]	2.929[a]	1.837[b]
4.0	1.022[ab]	1.361[b]	0.976[ab]	1.395[c]	3.008[a]	3.945[ab]	1.988[a]	1.986[c]	5.279[ab]	2.963[a]	1.781[c]
5.5	1.047[a]	1.351[b]	1.001[a]	1.351[d]	3.031[a]	3.854[b]	1.986[a]	1.941[c]	5.174[b]	2.987[a]	1.733[d]
p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0009	<0.001	<.0001
CV	2.3	3.2	2.4	2.4	2.5	3.2	3.2	2.2	3.0	2.6	2.0

Means followed by different letters are significantly different (P<0.05). BW=body weight; FI=feed intake; WG=weight gain; FCR=feed conversion ratio.

capacity to adequately respond to a wide range of diets. Those authors also say that this "adaptability" is mostly due to their avid appetite, which makes these modern birds respond less to changes in dietary energy levels than their ancestors. Sakomura *et al*. (2004), using 22- to 43-day-old broilers and three ME levels, observed that energy levels did not affect FI, but WG and FCR significantly improved when energy levels increased. On the other hand, Vieira *et al*. (2002), working with 4 and 8% dietary oil inclusion, verified a significant change only in FCR, and not in WG or FI, whereas Raber *et al*. (2008), using diets with increasing oil levels, found that birds adjusted their FI, reducing it (p<0.01). Longo (2000) suggests that birds present lower feed utilization as intake increases due to the lack of efficiency of the digestive enzymes, and consequently, lower nutrient absorption, which was not observed in the present study.

It must be noted that in both experiments, the inclusion of up to 5.5% oil had no negative effect on broiler performance during the starter phase. The idea that broilers are not capable of properly using fats in the beginning of their lives, because they have immature enterohepatic circulation, lower lipase activity, and lower apparent digestibility of lipids (Leeson & Summers, 1997; Nir *et al*., 1993; Frizzas *et al*., 1996; Zelenka *et al*., 2000), was not evidenced as performance loss due to the addition of oil in our experiments.

The results of the present study, as well as those of Raber *et al*. (2008) and Vieira *et al*. (2002), showed that modern broiler strains have high capacity of utilizing dietary fat. Dietary fat utilization improves as the digestive system matures; however, already in the starter phase, broilers presented excellent use of this nutrient.

As to the comparison between the two oils used in the present trials, there are no published studies on their effects on broiler performance. However, Zanini *et al*. (2006) found that broilers fed canola oil were heavier at 45 days of age than those receiving soybean oil, which shows that vegetable oils may be utilized differently. In the present study, only the FCR of grower broilers in EXP 2 was better when rice oil was supplied, but this difference was not observed in the starter phase or in the total experimental periods.

Metabolism responses in EXP 1 show that the metabolizability of dietary dry matter and fat were not influenced by oil type (Table 4). However, increasing oil levels had significant and positive effects on CMDM ($p<0.01$) and CMCF ($p<0.0001$), demonstrating the beneficial effect of increasing fat inclusion on diet utilization, independently of the type of oil included (Table 5). Raber (2008) and Vieira *et al.* (2002) also found the dietary fat utilization increased with oil inclusion levels up 5.5 and 8%, respectively. Therefore, increasing the use of fats in diets, independently of the type of oil, have beneficial effects. Fat increases digesta retention time, increasing the time of contact between digestive enzymes and the digesta, consequently improving feed digestibility.

Table 5. Coefficient of metabolizability of dry matter (CMDM) and coefficient of apparent metabolizability of crude fat (CMCF) of broiler diets containing rice oil or soybean oil at 1 to 5.5% inclusion levels, in the period of 28 to 30 days of age (EXP 1).

	CMDM (%)	CMCF (%)
Oil type		
Rice	68.9	57.8
Soybean	68.2	55.4
p	Ns	Ns
Oil inclusion level in the diet (%)		
1.0	66.7	49.6
2.5	67.7	56.3
4.0	69.3	63.8
5.5	70.7	66.3
p	0.01	0.0001
CV	3.5	9.4

Ns=not significant. Means followed by different letters are significantly different (P<0.05).

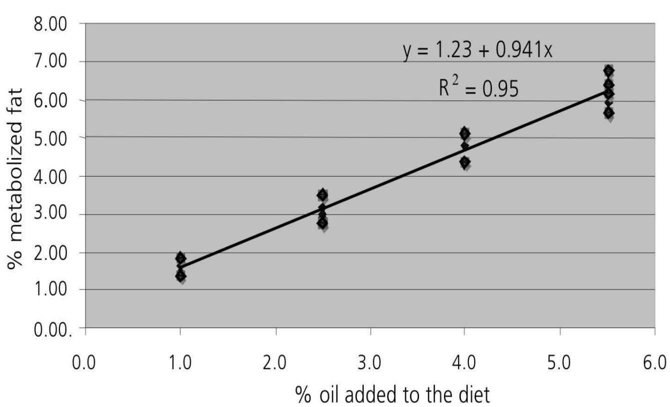


Figure 1. Regression line of rice oil metabolizability (EXP 1).

Figure 1 graphically shows the line and the equation resulting from the regression by the Lucas test (Van Soest, 1994). In this equation, the "b" value represents the metabolizability of semi-refined rice oil, which was 94%. The crude energy of this oil, obtained in calorimetric bomb, was 9260 kcal/kg. Therefore, the metabolizable energy value suggested for the formulation of broiler feeds is of approximately 8700 kcal/kg. This value is difficult to compare as neither in the Brazilian Tables for Poultry and Swine (2005), nor the Poultry NRC (1994) present ME values for this oil.

In EXP 2, there was no difference in carcass yield when the two oils were compared (Table 6), whereas increasing dietary oil levels negatively influenced breast yield, but did not affect the other parts.

Table 6. Carcass yield and yield of commercial cuts of broilers fed diets containing rice oil or soybean oil at 1 to 5.5% inclusion levels (EXP 2).

	Carcass	Breast	Leg	Thighs
Oil type				
Rice	70.7	28.5	12.8	17.0
Soybean	70.9	28.3	12.7	17.0
p	0.51	0.57	0.52	0.92
Oil inclusion level in the diet (%)				
1.0	71.2	28.9[a]	12.7	16.8
2.5	70.8	28.8[a]	12.7	16.8
4.0	70.6	27.8[b]	12.7	17.1
5.5	70.4	28.1[b]	12.8	17.0
p	0.15	0.03	0.85	0.54
CV (%)	1.7	5.2	5.4	4.8

Means followed by different letters are significantly different (P<0.05)

The obtained carcass yield results are similar to those reported by Anitha *et al.* (2006), who used increasing rice oil levels (0, 1, 2, 3, 4, or 5%) and also did not find any differences in the carcass yield of 42-day-old broilers. Nevertheless, those authors observed a linear decrease in thigh cholesterol level as rice oil level increased. Andreotti *et al.* (2004) also did not detect differences in carcass, breast, thighs+leg yields of broilers fed up to 9.9% soybean oil, as well as Tabeidian *et al.* (2005), who observed no influence of soybean oil inclusion levels (0, 2.5, 5, and 7.5%) on carcass yield. As to parts yield, the only difference between the mentioned studies and the present experiment was in breast yield. In the present trial, as opposed to those studies, breast yield decreased as dietary oil inclusion level increased. This may be explained by the fact that, due to the consumption of diets richer in energy, more fat is deposited in the carcass, and therefore breast weight relative to total carcass weight is reduced. Another possible explanation is that, as amino acid levels were maintained constant among treatments, birds fed the higher energy diet had lower feed intake, and therefore lower amino acid intake, resulting in lower breast muscle accretion.

Meat oxidative stability was not affected by oil type or inclusion levels (Table 7). There are no studies in literature comparing meat oxidative stability of broilers fed diets containing soybean oil or rice oil, but Zanini *et al.* (2006), working with the dietary addition of soybean oil or canola oil, did not find any difference in the oxidative stability of thigh or breast meats. The hypothesis that rice oil, as it contains gamma-orizanol, which is an antioxidant, could influence this parameter, was not confirmed.

Table 7. TBARS mean values (mg malondialdehyde/kg sample) in the thigh meat of broilers fed diets containing rice oil or soybean oil at 1 to 5.5% inclusion levels (EXP 2).

	TBARS value mg malondialdehyde /kg sample)
Oil type	
Rice	1.310
Soybean	1.324
P	Ns
Oil inclusion level in the diet (%)	
1.0	1.391
2.5	1.089
4.0	1.373
5.5	1.415
P	Ns
CV	56.1

Ns=not significant.

CONCLUSIONS

As semi-refined rice oil resulted similar responses in the evaluations made, and also promoted better feed conversion ratio during the period of 22 to 42 days of age, it may be used as an alternative to soybean soapstock in broiler diets. No advantage as to the antioxidant capacity of rice oil was demonstrated.

REFERENCES

Andreotti MO, Junqueira OM, Barbosa MJB, Cancherini LC, Araújo LF, Rodrigues EA. Tempo de trânsito intestinal, desempenho, característica de carcaça e composição corporal de frangos de corte alimentados com rações isoenergéticas formuladas com diferentes níveis de óleo de soja. Revista Brasileira de Zootecnia 2004; 33(4):870–879.

Association of Official Analytical. Official methods of analysis. 16th ed. Arlington: AOAC International; 1995. 1025p.

Berger A, Rein D, Schafer A, Monnard I, Gremaud G, Lambelet P, Bertoli C. Similar cholesterol-lowering properties of rice oil, with varied gamma-oryzanol, in mildly hypercholesterolemic men. European Journal of Nutrition 2005; 44(3):163-173.

Anitha B, Moorthy M, Viswanathan K. Performance of broilers fed with crude rice oil. International Journal of Poultry Science 2006; 5(11):1046-1052.

Anitha B, Moorthy M, Viswanathan K. Effect of Dietary Protein Levels and Soybean Oil Supplementation on Broiler Performance. The Journal of Poultry Science 2007; 44(3):283-290.

Frizzas AC. Efeito do uso de probiótico sobre o desempenho e atividade de enzimas digestivas de frangos de corte [dissertação]. Jaboticabal (SP): Universidade Estadual Paulista; 1996.

Fry AC, Bonner E, Lewis DL, Johnson RL, Stone MH, Kraemer WJ. The effects of gamma-oryzanol supplementation during resistance exercise training. International Journal of Sport Nutrition 1997; 7(4):318-329.

Gobesso AAO, Gonzaga IVF, Pastore WT, Ávila LA. Efeito da suplementação com óleo de arroz semi-refinado rico em gama-orizanol sobre o escore corporal, ganho de peso e digestibilidade da dieta de garanhões. Anais da 44ª Reunião Anual da Sociedade Brasileira de Zootecnia; 2007 Jul 24-27; Jaboticabal, SP. Brasil.

Henn JD, Ribeiro AML, Kessler AM. Comparação do valor nutritivo de farinhas de sangue e de farinhas de vísceras para suínos utilizando-se o método da proteína e gordura digestíveis e o método de substituição. Revista Brasileira de Zootecnia 2006; 35(4):1366-1372.

Juliano C, Cossu M, Alamanni MC, Piu L. Antioxidant activity of gamma-oryzanol: mechanism of action and its effect on oxidative stability of pharmaceutical oils. International Journal of Pharmaceutics 2005; 299:146-154.

Lara LJ, Baião NC, Aguilar FCR. Efeito de fontes lipídicas sobre o desempenho de frangos de corte. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 2005; 57(6):792-798.

Leeson S, Summers JD. Commercial poultry nutrition. 2nd ed. Guelph(ON): University Books; 1997.

Longo FA. Estudo do metabolismo energético e do crescimento em frangos de corte [dissertação]. Jaboticabal (SP): Universidade Estadual Paulista; 2000.

Nir I, Nitsan Z, Mahagna M. Comparative growth and development of the digestive organs and of some enzymes in broiler and egg type chicks after hatching. British Poultry Science 1993; 34:523-532.

National Research Council. Nutrient requirement of poultry. 9th ed. Washington (DC): National Academy of Sciences; 1994. p.155.

Paucar-Menacho LM, Silva LH, Sant'ana AS, Gonçalves LAG. Refino de óleo de farelo de arroz (*Oryza sativa* L.) em condições brandas para preservação do ã-orizanol. Ciência e Tecnologia de Alimentos 2007; 27:1-8.

Raber MR, Ribeiro AML, Kessler AM, Arnaiz V, Labres RV. Desempenho, metabolismo e níveis plasmáticos de colesterol e triglicerídeos em frangos de corte alimentados com óleo ácido e óleo de soja. Revista Ciência Rural 2008; 38 (6):1730-1736.

Rostagno HS, Albino LFT, Donzele JL. Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais. 2ed. Viçosa (MG): Universidade Federal de Viçosa; 2005.

Sakomura NK, Longo FA, Rabello CB, Watanabe K, Pelícia K, Freitas ER. Efeito do nível de energia metabolizável da dieta no desempenho e metabolismo energético de frangos de corte. Revista Brasileira de Zootecnia 2004; 33(6):1758-1767.

Statistic Analysis System. Painless windows, a handbook for SAS users. 2nd ed. Guelph (ON): Jodie Gilmore; 2001.

Scavariello EM, Arellano DB. Gamma-oryzanol: an important component in rice oil. Archivos Latinoamericanos de Nutrición 1998; 48(1):7-12.

Souza LP, Rodrigues CEC, Gonçalves CB, Meirelles AJA. Estudo da solubilidade do γ-orizanol em solventes etanólicos. Anais do 6º Congresso Brasileiro de Engenharia Química em Iniciação Científica da Unicamp; 2005; Campinas, SP. Brasil. [citado em 2009 jan 28]. Disponível em: <http://www.feq.unicamp.br/~cobeqic/ttd05.pdf>

Tabeidian A; Sadeghi GH, Pourreza J. Production Performance of Broilers Fed with Crude Rice oil. International Journal of Poultry Science 2005; 4(10):799-803.

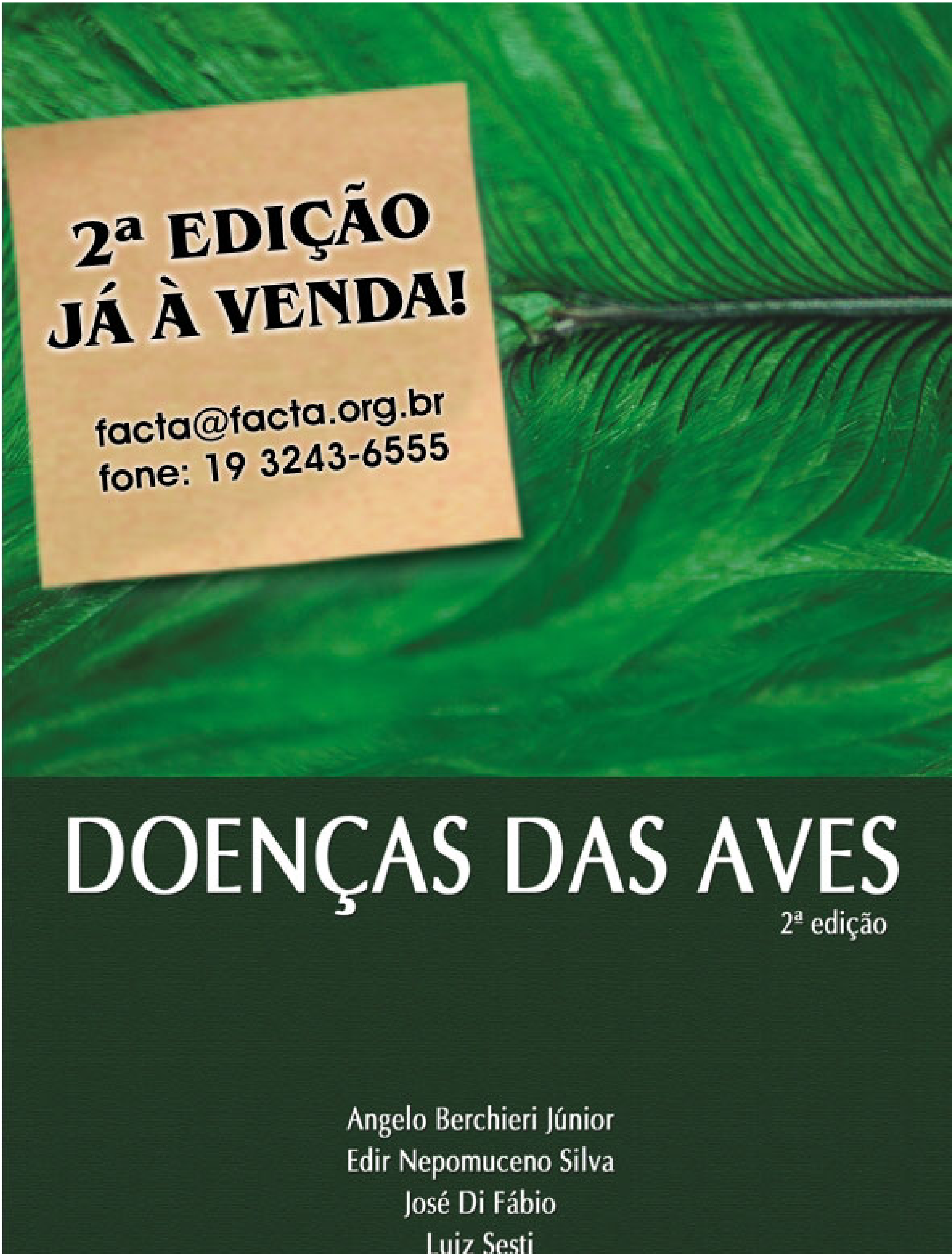
Van Soest PJ. Nutritional ecology of the ruminant. 2nd ed. New York (NY): Cornell University; 1994.

Vieira SL, Ribeiro AML, Kessler AM, Fernandes LM, Ebert AR, Eichner G. Utilização da energia de dietas para frangos de corte formuladas com óleo ácido de soja. Revista Brasileira de Ciência Avícola 2002; 4(2):127-139.

Wilson T, Nicolosi R, Woolfrey B, Kritchevsky D. Rice oil and oryzanol reduce plasma lipid and lipoprotein cholesterol concentrations and aortic cholesterol ester accumulation to a greater extent than ferulic acid in hypercholesterolemic hamsters. The Journal of Nutritional Biochemistry 2007; 18(2):105-112.

Zanini SF, Colnago GL, Bastos MR, Pessotti BMS, Casagrande FP, Lima VR. Oxidative stability and total lipids on thigh and breast meat of broilers fed diets with two fat sources and supplemented with conjugated linoleic acid. Lebensmittel-Wissenschaft und-Technologie-Food Science and Technology 2006; 39(7):717-723.

Zelenka J, Fajmonová E, Bla•ková E. Apparent digestibility of fat and nitrogen retention in young chicks. Czech Journal of Animal Science 2000; 45:457-462.


2ª EDIÇÃO
JÁ À VENDA!
facta@facta.org.br
fone: 19 3243-6555
DOENÇAS DAS AVES
2ª edição
Angelo Berchieri Júnior
Edir Nepomuceno Silva
José Di Fábio
Luiz Sesti