Improving Qualitative Properties of Extruded Linseed as Mixed with Different Absorbent Materials in Iran

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ABSTRACT

Limited data exist about the production of extruded linseed as a feed ingredient in farm animal nutrition. The objective of this study was to produce and evaluate extruded linseed mixed with alfalfa hay, pistachio by-products, and sugar beet pulp or corn grain in different proportions of linseed: alfalfa hay: pistachio by-products at ratios of 70:15:15, 70:20:10, 70:10:20, and 80:10:10 for quality parameters and *in situ* rumen Dry Matter (DM) degradability. Using a completely randomized design, the treatment containing alfalfa hay had higher Extrusion Effectiveness (EE), Water Holding Capacity (WHC), and Angle of Repose (AR), but lower Oil Loss (OL) and Bulk Density (BD) than other treatments ($P < 0.05$). There were no differences among extruded linseed products with different ratios of linseed: alfalfa: pistachio by-products for EE, WHC, and AR ($P > 0.05$). The treatment with an 80:10:10 ratio had the highest OL among all treatments and the treatment with a 70:15:15 ratio had lower BD than the others ($P < 0.05$). The DM degradability parameters of extruded products was affected by the absorbents and the treatment containing alfalfa hay had higher potential DM degradability than other treatments ($P < 0.05$). In conclusion, extruded treatment with alfalfa hay had the highest EE, oil retention capacity and potential rumen DM degradability compared to other treatments. In addition, extruded linseed product with an 80:10:10 ratio of linseed: alfalfa hay: pistachio by-products had higher OL than the other ratios.

Keywords: Alfalfa, Fat absorption capacity, Pistachio by-products.

INTRODUCTION

Consistent with the progress of studies on the use of linseed in the diet of dairy cows and increasing consumer interest in healthier dairy products, dairy farmers became interested in using linseed in the diet of dairy cows to manipulate milk fatty acids. Linseed is a rich source of linolenic acid, averaging 18% of the total seed weight and constituting 53% of the total Fatty Acid (FA) (Gonthier *et al*., 2004). Since the simplest way to modify milk fat composition is to supplement cow diets with unsaturated lipids (Chilliard *et al*., 2007), polyunsaturated FA-rich feedstuffs, such as linseed, are added to dairy cow diets to modify milk FA profiles by increasing α-linolenic acid and conjugated linoleic acid content. Feeding whole, rolled, or extruded linseed to dairy cows increases concentration of milk unsaturated FA and decreases the concentration of saturated FA, particularly *C*16:0 (Mustafa *et al*., 2003a; Akraim *et al*., 2007; Cattani *et al*., 2014).

However, feeding linseed produced relatively small changes in the concentration of *C*18:2 and *C*18:3 in milk due to the

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extensive biohydrogenation of these FA in the rumen (Ferlay *et al*., 2011). Altering the physical structure of linseed through heat treatment may help to protect the dietary FA of oilseeds from ruminal biohydrogenation (Chouinard *et al*., 1997). Kennelly (1996) suggested that the application of heat to high fat feedstuffs, such as linseed, can denature the protein matrix surrounding the fat droplets and, therefore, protects fat from ruminal biohydrogenation.

Extrusion is a heat treatment that has been used extensively in the production of animal feed and can be useful to protect oilseeds from ruminal degradability (Pena *et al*., 1986; Chouinard *et al*., 1997). Sterk *et al*. (2010) reported that the extrusion of whole linseed decreased the biohydrogenation of $C18:3n$-3 in *in vitro* culture. Indeed, during extrusion, several operations take place, such as grinding, hydration, mixing, shearing, thermal treatment, gelatinization, protein denaturation, destruction of microorganisms and some toxic compounds, shaping, expanding, and partial dehydration (Riaz, 2005). During the oilseed extrusion process, the rapid release of intracellular oil may lead to considerable oil losses (Akraim *et al*., 2007). Furthermore, when this oil is extracted, it is exposed to high temperatures and air, which may probably increase the rate of oxidation and reduce the desirability of the feed ingredient from a farmer/producer perspective as it smells bad and tastes rancid. Excess oil that is not retained by the feed ingredient may be lost during transport and storage, which can be considered as an economic loss, as the desired and health beneficial ingredient of oilseed is its oil (Eggie, 2010). A successful resolution of the problems is selection and addition of a binder (absorbent) to oilseed before extrusion process, that may help to reduce oil losses during extrusion of oilseeds (Akraim *et al*., 2007; Eggie, 2010).

To date, limited data exist about the production of extruded linseed as a feedstuff for animal nutrition. The primary objective of the current study was the production of extruded linseed mixed with alfalfa hay,

pistachio by-products, sugar beet pulp or corn grain and in different proportions of linseed: alfalfa hay: pistachio by-products at ratios of 70:15:15, 70:20:10, 70:10:20, and 80:10:10. The secondary objective was to evaluate the extruded products for quality parameters and *in situ* rumen DM degradability.

MATERIALS AND METHODS

This study was conducted in four phases: (1) Fat Absorption Capacity (FAC) evaluation of absorbent materials; (2) Extrusion trial; (3) Analysis of quality parameters, and (4) *In situ* rumen DM degradability.

Fat Absorption Capacity Evaluation

In this step, at first, alfalfa hay, pistachio by-products, sugar beet pulp and corn grain were ground using a coffee grinder. These materials were ground within relative consistency of each other by visual assessment. In the following steps, FAC was determined using the method of Lin *et al*. (1974).

Extrusion Process

For the extrusion trial, a mixture with a mass ratio of 70:30 of linseed and different absorbents (alfalfa hay, pistachio by-products, and sugar beet pulp or corn grain) was prepared. The extrusion was performed in a double screw extruder (DS56-III, Jinan Saixin Machinery Co., Shandong, China), consisting of three independent zones of controlled temperature in the barrel. The temperature profiles in the first and second zones were kept constant at 70 and 80ºC, respectively, and the die head temperature was about 110ºC. The extruded material was cut with a die face cutter as it left the extrusion die. After stable conditions were established, about 700 g of extruded product

was collected and dried in air oven at 40ºC for 24 hours. Extruded material was stored at 4ºC in plastic bags for further analysis. In another step of this experiment, we produced extruded linseed using a mix of alfalfa hay and pistachio by-products as absorbents. In fact, in this step, a mixture of linseed, alfalfa hay, and pistachio by-products in different mass ratios (70:15:15; 70:20:10; 70:10:20 and 80:10:10) was prepared and extruded as described above, and the final products were evaluated for quality parameters. All experiments were conducted in duplicate.

Analysis for Quality Parameters

Extrusion Effectiveness (EE) is the ability of the extruder to grind whole seeds, measured by comparing the number of whole seeds in a sample before and extrusion. In this study, EE was determined using the method of Eggie (2010). The Oil Retention (OR) was measured using the method of Eggie (2010). Water Holding Capacity (WHC) was determined using a modified version of the AACC 56-30.01 method (AACC International, 1999) as modified by Eggie (2010). Bulk Density (BD) was determined using a modified version of ASAE Standard S269.4 DEC 01(ASAE, 2007) as modified by Eggie (2010). Angle of Repose (AR) was measured using the established method for the Carr Angle of Repose (Carr, 1965) and described by ASTM D6393-99 (ASTM, 2006). According to Carr (1965), low angles of 30° to 40° indicate a material with relatively easy flowing characteristics and high angles of 50° to 60° represent materials with difficult flowing conditions (Ganesan *et al*., 2005).

In situ Rumen Dry Matter Degradability

A measurement of *in situ* DM degradability of the treated samples was performed in 4 rumen-fistulated dairy cows using the nylon bag technique (Ørskov and McDonald, 1979). The nylon bags (9×18 cm^2, pore size 50 μm) were filled with 5 g of samples and put into the rumen. Table 1 shows the ingredient composition of the Total Mixed Ration (TMR) offered to the dairy cows in two equal feedings at 08:00 and 16:00 hours.

The bags were removed at 2, 4, 8, 12, 24 and 48 hours after the start of incubation, and each bag was washed immediately with cold tap water until color disappeared.

For disappearance at t_0 time, the un-incubated bags were simply washed in water. All washed bags were dried in a forced-air oven at 65°C for 48 hours. Disappearance of DM at each incubation time was estimated from the proportion remaining after incubation in the rumen.

Calculations and Statistical Analysis

The rate and extent of DM degradation were estimated according to the equation: $P = a + b (1 - e^{-ct})$, where P is the disappearance rate at time t, a is rapidly

Table 1. Ingredient of the total mixed ration for fistulated dairy cow.

Ingredients	DM (%)
Alfalfa	20
Corn silage	17
Extruded Linseed mixture	8
Corn grain	18
Barley grain	10
Soybean meal	10.5
Rapeseed	7
Meat powder	3.5
Sugar beet pulp	4.6
Calcium carbonate	0.5
Vitamin-mineral mix	0.7
Sodium chloride	0.2
Chemical composition	**g kg^{-1} DM**
CP	17.5
NDF	30
Forage NDF	17.8
ADF	19
Ether extract	4.6
Ca	1.2
P	0.6

degradable DM fraction, *b* is slowly degradable DM fraction in the rumen, *c* is the rate constant of degradation of *b*, and *t* represents the time of incubation.

Effective Degradability of DM (EDDM) was calculated as *EDDM= a+(b × c)/(c + Kp),* where *k* is the fractional outflow rate (k= 0.05) from the rumen (per hour), with *a*, *b*, and *c* as described above (Ørskov and McDonald, 1979).

Data were analyzed in a completely randomized design using the general linear model procedure of SAS 9.2 (2003).

The statistical model used, was as following:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where, Y_{ij} is the observation; μ is the overall mean; T_i is the effect of treatments and e_{ij} is the random error. Significant differences between individual means were identified using Duncan's multiple range test at a 0.05 probability level.

RESULTS AND DISCUSSION

Data on FAC for different common feedstuffs as absorbent indicated that alfalfa hay had the highest FAC (P<0.05) as compared to the other materials, and

pistachio by-products, sugar beet pulp and corn grain had similar quality for oil absorption (Table 2). Eggie (2010) compared the FAC of several absorbents and reported that this parameter was higher in alfalfa in contrast to soy hulls, corn gluten, ground wheat, beet pulp and corn grain.

Quality Parameters

Extruded linseed products containing different absorbents (Table 3) had different quality parameters (P< 0.05).

Extrusion Effectiveness

Extruded product with alfalfa hay had the highest (100%) EE compared to the other treatments (P< 0.05). Therefore, it may probably improve the digestibility of extruded linseed product in total digestive system of animals (Colovic *et al*., 2010) and, subsequently, a reduced amount of whole linseed can be observed in animal feces. Indeed, linseeds are quite small and the mucilage present in the outer coating lends the seed a very slippery quality; the combination of which makes them difficult

Table 2. Fat Absorption Capacity (FAC) of different feedstuffs.

Item	Alfalfa hay	Pistachio by-products	Sugar beet pulp	Corn grain	SEM [a]
			Feedstuffs		
%FAC	295.66[a]	207.83[b]	204.5[b]	179.66[b]	9.597

[a] Standard Error of Mean. Means whit different superscripts (a and b) are significantly different (P< 0.05).

Table 3. Quality parameters of extruded linseed products with different absorbents.

Items[c]	70:30 AL	70:30 PIS	70:30 SBP	70:30 CG	SEM [b]
		Extruded linseed mixture [a]			
EE (%) [c]	100[a]	98.76[b]	97.92[c]	98.93[b]	0.104
OL (g) [d]	0.10[c]	1.03[b]	1.52[a]	0.93[b]	0.043
WHC [e]	6.81[a]	6.12[a]	2.37[b]	3.64[b]	0.531
BD (g cm^{-3}) [f]	0.74[c]	1.14[ab]	1.12[b]	1.16[a]	0.009
AR (°) [g]	46.23	39.01	40.82	35.3	-

[a] Extruded linseed mixture with 70% linseed and 30% AL (Alfalfa hay), PIS (Pistachio by-products), SBP (Sugar Beet Pulp), [b] Standard Error of Mean. Means whit different superscripts (a, b, and c) are significantly different , [c] Extrusion Effectiveness; [d] Oil Lost; [e] Water Holding Capacity (Measured in g H$_2$O per gram dry matter) ; [f] Bulk Density, [g] Angle of Repose.

to handle and process (Eggie, 2010). Therefore, it seems that in the linseed extrusion process, whatever the initial mixture (linseed: absorbent) be better able to create friction between the screws and seeds, consequently, the screws can be better able to crush the grains, so that, in the final product, fewer whole seeds will be observed.

Oil Retention

The OL test determined that treatment with alfalfa hay generated the best quality for OL (P< 0.05), as anticipated from the data of the FAC experiment (Table 2). Indeed, it improved the OL of extruded linseed compared to treatments with pistachio by-products, sugar beet pulp and corn grain by 10, 15, and 9 times, respectively, and this result was similar to the finding of Eggie (2010). It seems that there is a positive relationship between the FAC of absorbent materials and the OL of final extruded linseed (Eggie, 2010). In fact, OL is the ability of the extruded products to retain oil, which is related to the type of absorbent and the ratio of oilseed: absorbent in the extrusion process (Eggie, 2010). Eggie (2010) reported that the extruded product made with a mixture of linseed and alfalfa (75:25) had higher OL than the mixture of linseed and soy hulls or corn gluten.

Water Holding Capacity

Water holding capacity was tested to observe how the behavior of the material would be changed due to extrusion in the presence of water. This test demonstrated that treatments with alfalfa hay and pistachio by-products had higher WHC than treatment with sugar beet pulp and corn grain (P< 0.05). Water holding capacity is closely related to the fiber content of a material and the WHC of that fiber (Eggie, 2010). Thus, it seems that the differences in WHC

between these treatments were related to differences in fiber content and the type of fiber of their absorbents.

Bulk Density

Bulk density was affected by the type of absorbent, such that extruded samples containing corn grain, pistachio by-products, and sugar beet pulp had a higher density than extruded samples containing alfalfa hay (P< 0.05). Eggie (2010) reported that there was significant difference between extruded linseed products produced with alfalfa, soy hulls, or corn gluten. Extruded material with corn gluten had the highest BD compared to the other two products.

Angle of Repose

There were slight differences in AR among extruded linseed products. This index indicated that product samples containing corn grain, pistachio by-products, and sugar beet pulp had relatively easy flow characteristics, while the product with alfalfa hay had a little more difficulty with flow than the other products.

Eggie (2010) observed no differences among extruded linseed products containing 25% alfalfa, soy hulls, or corn gluten for the AR parameter and all of these products had acceptable flow characteristics.

Quality parameters for extruded linseed products with different proportions of linseed: alfalfa hay: pistachio by-products (Table 4) indicated that there were no differences among treatments for EE, WHC and AR (P> 0.05). Oil lost was higher in treatment with an 80: 10: 10 ratio compared to other treatments (P< 0.05), but there were no differences among other three treatments for this factor (P> 0.05). Therefore, it can be concluded that with a decrease in the ratio of absorbents, the FAC of final product decreased and, therefore, the OL increased. Furthermore, data showed that BD was higher for treatment with a 70: 15: 15 ratio

Table 4. Quality parameters of extruded linseed mixed with alfalfa hay and pistachio by-products.

Items	Extruded linseed mixture [a]				SEM [b]
	70:15:15	70:20:10	70:10:20	80:10:10	
EE (%) [c]	98.62	98.55	98.53	99.46	3.110
OL (g) [d]	0.071[b]	0.066[b]	0.068[b]	0.103[a]	0.0034
WHC [e]	6.02	7.04	6.64	6.98	0.002
BD (g cm^{-3}) [f]	0.65[b]	0.74[a]	0.72[a]	0.72[a]	0.011
AR (º) [g]	44.87	47.07	46.16	46.68	0.699

[a] Extruded linseed mixture with different proportions of linseed: alfalfa hay: pistachio by-products. [b] Standard Error of Mean. Means whit different superscripts (a and b) are significantly different (P< 0.05). [c] Extrusion Effectiveness; [d] Oil Lost; [e] Water Holding Capacity (Measured in g H_2O per gram dry matter); [f] Bulk Density, [g] Angle of Repose.

compared to the other treatments (P< 0.05), but there were no differences among the other treatments for this parameter.

In Situ Rumen Dry Matter Degradability

The data of DM degradation parameters for treatments containing alfalfa hay, pistachio by-products, and sugar beet pulp are given in Table 5. Dry matter degradability parameters were different among treatments (P< 0.05), and the treatment with alfalfa hay had lowest a and c fraction and highest b fraction among all treatments (P< 0.05). In addition, treatment with alfalfa hay and sugar beet pulp had higher potential DM degradability compared to treatment with pistachio by-products (P< 0.05). Effective DM degradability was affected by different absorbents and it was lowest in the extruded product containing alfalfa hay (P< 0.05).

In our study, it seems that the DM degradability parameters of these extruded products conformed to their absorbents degradation. Since extruded linseed with alfalfa hay had the highest slowly degradable DM, it can increase the advantages of this product for using in ruminant nutrition. Because this fraction can move to other parts of gastrointestinal system, poly-unsaturated fatty acids content in extruded linseed can pass from rumen biohydrogenation. In fact, this property can be useful for increasing the CLA content of milk and meat in ruminants (Griinari and Shingfield, 2002).

Mustafa *et al* (2003b) reported that extrusion increased ruminal DM and crude protein degradability of linseed. In addition, Eggie (2010) indicated that the disappearance of DM in the rumen significantly increased by extrusion, but in contrast to our data, the percentage of this parameter among different extruded linseed

Table 5. Degradation parameters for different extruded linseed products.

Degradation parameter [c]	Extruded linseed mixture [a]			SEM [b]
	70:30 AL	70:30 PIS	70:30 SBP	
a (mg g^{-1})	14.29[b]	21.72[a]	21.96[a]	0.424
b (mg g^{-1})	69.33[a]	55.26[c]	61.04[b]	0.301
c (h^{-1}%)	0.046[c]	0.119[a]	0.114[b]	0.001
Potential degradability (a+b) (mg g^{-1})	83.63[a]	76.98[b]	83.01[a]	0.611
Effective degradability (%)	47.83[c]	60.70[b]	64.52[a]	0.327

[a] Extruded linseed mixture with 70% linseed and 30% AL (Alfalfa hay), PIS (Pistachio by-products), SBP (Sugar Beet Pulp). [b] SEM: Standard Error of Mean. Means whit different superscripts (a, b, and c) are significantly different (P<0.05). [c] a is rapidly degradable DM fraction, b is slowly degradable DM fraction in the rumen, c is the rate constant of degradation of b.

products (containing 25% alfalfa, soy hulls or corn gluten) was the same.

CONCLUSIONS

In conclusion, alfalfa hay had the highest FAC compared to the other feedstuffs and the extruded treatment with alfalfa hay had highest EE, oil retention capacity and potential *in situ* rumen DM degradability compared to the other treatments. It seems that among these treatments, the treatment with alfalfa hay is the best extruded linseed product for ruminant nutrition, because of its highest oil retention capacity; it can prepare more benefical effect of linseed oil in the diet of ruminants. In addition, although the extruded linseed with an 80:10:10 ratio of linseed:alfalfa hay:pistachio by-products had higher OL than treatments with other ratios, it can be the best combination for using in ruminant nutrition because it can prepare 10% linseed more than the other treatments, while its OL is not much higher than other ratios.

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بهبود خصوصیات کیفی دانه کتان اکسترود شده بصورت مخلوط با مواد جاذب مختلف در ایران

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چکیده

اطلاعات محدودی در زمینه نحوه تولید دانه کتان اکسترود شده برای استفاده در تغذیه دام وجود دارد. در این پژوهش، دانه کتان اکسترود شده بصورت مخلوط با یونجه خشک، فرآورده های فرعی پسته، تفاله چغندر یا دانه ذرت و همچنین مخلوط، فرآورده های فرعی پسته: یونجه خشک: دانه کتان با نسبت های ۱۵:۱۵:۷۰، ۱۰:۲۰:۷۰، ۲۰:۱۰:۷۰ و ۱۰:۱۰:۸۰ تولید و برای خصوصیات کیفی مختلف و تجزیه پذیری شکمبه ای مورد ارزیابی قرار گرفت. در قالب یک طرح کاملا تصادفی، تیمار حاوی یونجه خشک، بالاترین کارآیی اکستروژن (EE)، ظرفیت نگهداری آب (WHC) و شاخص زاویه ریزش (AR)، و کمترین میزان اتلاف روغن (OL) و جرم حجمی (BD) را در مقایسه با سایر تیمارها دارا بود (P<0.05). بین تیمارهای حاوی نسبت های مختلف فرآورده های فرعی پسته: یونجه خشک:

دانه کتان، از نظر EE، WHC و AR تفاوتی وجود نداشت (P>0.05). تیمار با نسبت ۱۰:۱۰:۸۰ (فرآورده های فرعی پسته: یونجه خشک: دانه کتان) بیشترین OL و تیمار با نسبت ۱۵:۱۵:۷۰ کمترین BD را در مقایسه با سایر تیمارها دارا بودند (P<0.05). تجزیه پذیری شکمبه ای دانه کتان اکسترود شده، تحت تاثیر نوع جاذب قرار گرفت و تیمار حاوی یونجه خشک بالاترین پتانسیل تجزیه پذیری را دارا بود (P<0.05). بر این اساس، تیمار حاوی یونجه خشک دارای بالاترین EE، ظرفیت نگهداری روغن و پتانسیل تجزیه پذیری شکمبه ای را در مقایسه با سایر تیمار ها دارا بود. بعلاوه، در بین تیمار های حاوی نسبت های مختلف فرآورده های فرعی پسته: یونجه خشک: دانه کتان، تیمار ۱۰:۱۰:۸۰ بالاترین میزان اتلاف روغن را داشت.