EFFECT OF DIETS CONTAINING WHOLE WHITE LUPIN SEEDS ON MILK COMPOSITION AND YIELD OF RABBIT DOES AND PERFORMANCE AND HEALTH OF THEIR LITTERS

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ABSTRACT

The aim of this study was the evaluate the effect of lactation and weaning diets based on whole white lupin seeds (*Lupinus albus* cv. Amiga) on milk composition and yield of the non-pregnant rabbit does, as well as on performance and health of their litters. The lactation diet SL contained both soybean and sunflower meals as the main protein source, whereas the lactation diet LL was based on whole white lupin seeds. The weaning diet SW had soybean meal as the main protein source, whereas the weaning diet LW was based on whole white lupin seeds. A total of 32 (16 per treatment) Hyplus PS 19 rabbit does (all does at the 2nd parturition) were allocated to two groups and fed one of the two experimental lactation diets for 30 days. The litters were standardised to 9 kits on the day of birth, and were fed one of the two weaning diets from 17 to 72 d of age. At the weaning (30 d of age), 6 rabbits per litter were used for the growth performance and health risk index evaluation. There was a better feed conversion ratio (P=0.003) between 1 and 21 day of the lactation in the does fed the LL diet than in those fed the SL diet. There was a higher milk yield between 22 and 30 day of the lactation (P=0.044), as well as for the entire lactation (P=0.094), in the rabbit does fed the LL diet. At 21 days of lactation, there was a significantly lower dry matter and protein content in milk from the does fed the LL diet. However, protein output per kg live weight was not significantly affected by dietary treatment. Milk fat content was non-significantly higher and fat output per kg live weight turned out significantly higher in the does fed the LL diet. Milk of the does fed the LL diet contained more oleic, α-linolenic and EPA acid and less linoleic acid and short-chain fatty acids. There was a better milk conversion in litters of the rabbit does which were fed the LL diet (1.96 *vs.* 2.04, P=0.048). There was no mortality of kits before weaning. After weaning, weight gain, feed intake, feed conversion ratio or live weight at the end of the experiment was not affected by dietary treatment. However, health risk index (sum of mortality and morbidity) was significantly lower in rabbits fed the LW diet than in those fed the SW diet (3.0% *vs* 16.7%, P=0.016). It can be concluded that whole white lupin seeds is a suitable protein source for lactating rabbit does. The diet based on whole white lupin led to higher milk yield, milk fat output per kg live weight, C 18:3n-3 and C 20:5n-3 content in milk.

Key words: Rabbit, diet, White Lupin, milk, health status.

INTRODUCTION

Recent research has shown that whole white lupin seeds (*Lupinus albus* cv. Amiga) are a suitable dietary crude protein source for fattening rabbits that can fully replace traditionally used protein sources such as soybean meal or sunflower meal (Volek and Marounek, 2009). Furthermore, Volek and Marounek (2011) reported that feeding rabbits a diet based on whole white lupin seeds (*Lupinus albus* cv. Amiga) decreased the content of saturated fatty acids, the PUFA n-6/PUFA n-3 ratio, and the saturation, atherogenic and thrombogenic indexes in hind leg meat and perirenal fat compared with rabbits fed a diet based on sunflower meal. To our knowledge, however, there are no reports in the available literature regarding the effect of a lupin diet on the performance of rabbit does during the lactation period, and health status of their litters before and after weaning.

Thus, the aim of this study was the evaluate the effect of lactation and weaning diets based on whole white lupin seeds (*Lupinus albus* cv. Amiga) on milk composition and yield of the non-pregnant rabbit does, as well as on performance and health of their litters.

MATERIALS AND METHODS

Diets, animals and experimental design

Table 1: Ingredients and chemical composition (g/kg as-fed basis unless otherwise stated) of diets based on soybean and sunflower meals (SL and SW) or whole white lupin seeds (LL and LW).

	Lactation diet		Weaning diet	
	SL	LL	SW	LW
Ingredients				
Alfalfa meal	300	300	300	300
Soybean meal, 480 g CP/kg	130	0	70	0
Sunflower meal, 280 g CP/kg	50	0	0	0
White lupin seeds	0	250	0	120
Wheat bran	80	50	330	320
Sugar beet pulp	20	20	70	50
Oats	160	130	150	120
Barley	230	220	50	60
Vitamin-mineral supplement[1]	10	10	10	10
Dicalcium phosphate	7	7	5	5
Limestone	10	10	10	10
Salt	3	3	5	5
Determined values (n = 2)				
Dry matter	896	892	889	894
Crude protein	187	176	163	161
Neutral detergent fibre	265	267	368	355
Acid detergent fibre	158	167	181	190
Lignin	46	43	45	42
Starch	232	214	167	158
Ether extract	23	41	24	32
Myristic acid (C 14:0)[2]	0.38	0.67	-	-
Palmitic acid (C 16:0)[2]	18.74	16.76	-	-
Margaric acid (C 17:0)[2]	0.27	0.59	-	-
Stearic acid (C 18:0)[2]	4.00	7.21	-	-
Oleic acid (C 18:1n-9)[2]	12.59	32.86	-	-
Linoleic acid (C 18:2n-6)[2]	40.08	23.23	-	-
α-Linolenic acid (C 18:3n-3)[2]	16.92	12.21	-	-
EPA (C 20:5n-3)[2]	0.06	0.46	-	-
Gross energy (MJ/kg)	16.8	17.2	16.8	16.7
Calculated values				
Lysine[3]	8.4	8.4	8.3	8.0
Methionine + cysteine[3]	6.1	6.1	6.0	5.8
Threonine[3]	7.0	7.0	6.8	6.8
Digestible crude protein to digestible energy ratio (g /MJ)[4]	-	-	11.2	11.2

[1]also including per kg of feed: L-lysine, 0 and 300 mg in SL and LL diets, respectively; DL-methionine, 300 and 1000 mg in SL and LL diets, respectively; L-threonine, 500 and 500 mg in SL and LL diets, respectively. [2]% of total fatty acid. [3]Calculated from Maertens *et al.* (2002). [4]Calculated from digestibility coefficients obtained in the digestibility trial (between 50 and 54 d old).

Two lactation diets (SL and LL diet) and the 2 weaning diets (SW and LW diet) were formulated (Table 1). The SL diet contained both soybean and sunflower meal as the main protein source, whereas the LL diet was based on whole white lupin seeds. Synthetic amino acids were added to the vitamin-mineral premix in substitution of the premix carrier (wheat flour). The fatty acid (FA) profile of the LL diet reflected the typical fatty acid profile of white lupin seeds (Volek and Marounek, 2011). The SW diet had soybean meal as the main protein source, whereas the LW diet was based on whole white lupin seeds. All diets were offered as 3 mm pellets with a length 5-10 mm.

A total of 32 (16 per treatment) Hyplus PS 19 rabbit does (all does at the 2^{nd} parturition) were allocated to two groups and fed *ad libitum* one of the two experimental lactation diets for the 30 days.

The litters were standardised to 9 kits on the day of birth, and housed with their mothers in modified cages (92 x 72 x 45 cm) with two feeders allowing the distribution of solid feed separately for does and the kits. Briefly, the nest box (inside of cage) and a straight piece of wire mesh fixed in the middle of the cage divide it in two parts. The nest box had two enters (to mother or to litter part of cage). Enters for mothers were closed but not enters for litters. The former enters were once daily opened for 10 minute at fixed time (09:00 am). Feed intake and milk yield (11 does per treatment) were measured daily for the entire lactation. Milk yield was measured by weighing the doe immediately before and after suckling. The rest of does (5 per treatment) were used for the evaluation of the effect of the lactation diets on milk composition at 21 days of lactation. Milk was collected manually by gently massaging the mammary gland. Volumes of 25 to 30 ml per doe were obtained. Litters were offered *ad libitum* one of the two weaning diets from 17 to 72 d of age. At the weaning (30 d of age), 6 rabbits per litter (66 per treatment) were used for the growth performance and health risk index evaluation. Rabbits were collectively housed (3 animals per cage) in wire net cages (80 x 60 x 45 cm). In addition, one rabbit per litter (11 per treatment) was housed in individual cages (50 x 40 x 42.5 cm) and used for the determination of digestible crude protein to digestible energy ratio of the weaning diets (Table 1).

Analyses

Milk, diets and faeces were analysed by AOAC (1984) methods. The FA composition of diets and milk was determined after chloroform-methanol extraction of total lipids. Gas chromatography of methyl esters was performed using HP 6890 chromatograph (Agilent Technologies, Inc.) with a programmed 60 m DB-23 capillary column (150-230°C). Data on milk yield and composition, as well as on growth performance, were analysed by the GLM procedure using a one-way ANOVA (SAS, 2001). Health status was analysed using the chi-square test. Differences among treatment means with $P<0.05$ were accepted as representing statistically significant differences.

RESULTS AND DISSCUSION

There were no significant differences between treatments with regard to dry matter intake or live weight of the does for the entire lactation (Table 2). There was a higher milk yield between 1 and 21 day of the lactation (P= 0.226) and between 22 and 30 day of the lactation (P=0.044), as well as for the entire lactation (P=0.094), in the rabbit does fed the LL diet, probably associated with a higher ether extract dietary content and intake in the LL diet (Pascual *et al*., 2003). At 21 days of lactation, there was a significantly lower dry matter and protein content in milk from the does fed the LL diet (Table 3), probably associated with the higher daily milk production in these does (Maertens *et al*., 2006).

However, protein output per kg live weight was not significantly affected by dietary treatment. Milk fat content was non-significantly higher and fat output per kg live weight turned out significantly higher in the does fed the LL diet, probably associated with lupin protein because the slightly higher ether extract dietary content in the LL diet does not seem to affect milk fat content (Pascual *et al*., 2003). In lactating rats, Bettzieche *et al*. (2009) showed that lupin protein is hypocholesterolemic and increases milk fat content by influencing the expression of genes involved in cholesterol and triglyceride synthesis. Higher, but non-significantly, milk yield between 1 and 21 day of lactation and higher fat output at 21 days of lactation without variation of feed intake, would explain better feed conversion ratio (P=0.003) between 1 and 21 day of the lactation in the does fed the diet based on White Lupin than in those fed the diet based on soybean and sunflower meals.

In the present study (Table 3), the FA profile of milk from the does fed the SL diet was in line with the others authors (Maertens *et al*., 2006). However, milk of the does fed the LL diet contained more C 18:1n-9 and less C 18:2n-6, which reflected the typical FA profile of white lupin seeds (Volek and Marounek, 2011).

Table 2: Milk yield and performance of rabbit does fed the lactation diet based on soybean and sunflower meals (SL) or whole white lupin seeds (LL).

	Diet			
	SL	LL	RMSE[1]	P
Live weight (g) of does at:				
Partum	4246	4208	622	0.887
Weaning[2]	4477	4389	558	0.606
Intake of does (1 to 21 days)				
Dry matter (g / kg live weight$^{0.75}$ / d)	95.2	96.9	9.1	0.673
Crude protein (g / kg live weight$^{0.75}$ / d)	19.8	18.7	1.8	0.176
Ether extract (g / kg live weight$^{0.75}$ / d)	2.4	4.4	0.3	<.001
Intake of does (22 to 30 days)				
Dry matter (g / kg live weight$^{0.75}$ / d)	97.9	99.2	11.1	0.794
Crude protein (g / kg live weight$^{0.75}$ / d)	20.3	19.1	2.3	0.221
Ether extract (g / kg live weight$^{0.75}$ / d)	2.5	4.6	0.4	<.001
Milk yield (g)				
1 to 7 days of lactation	1173	1219	161	0.519
8 to 14 days of lactation	1757	1846	221	0.361
15 to 21 days of lactation	1889	2080	305	0.157
1 to 21 days of lactation	4819	5144	611	0.226
22 to 30 days of lactation	2063	2493	477	0.044
1 to 30 days of lactation	6902	7636	984	0.094
Feed conversion ratio:				
1 to 21 days of lactation[3]	3.18	2.80	0.27	0.003
22 to 30 days of lactation[4]	2.01	1.96	0.17	0.524

[1]root mean square error (n = 11 does per group). [2]at 30 days of lactation. [3]as feed intake of does from 1 to 21 days (kg) per litter weight gain from 1 to 21 days (kg). [4]as feed intake of does and litters from 22 to 30 days (kg) per litter weight gain from 22 to 30 days (kg).

Table 3: Milk composition, and milk, fat and protein output at 21 d of lactation in rabbit does fed the lactation diet based on soybean and sunflower meals (SL) or whole white lupin seeds (LL).

	Diet			
	SL	LL	RMSE[1]	*P*
Live weight (g)	4558	4405	668	0.599
Milk composition (g/100 g)				
Dry matter	27.4	23.3	2.0	0.011
Protein	10.3	8.9	0.8	0.021
Fat	13.3	14.3	2.5	0.528
Ash	2.0	1.9	0.1	0.282
Caprylic acid (C 8:0)[2]	25.63	23.02	0.59	0.001
Capric acid (C 10:0)[2]	23.91	21.97	0.17	0.001
Lauric acid (C 12:0)[2]	3.37	3.19	0.23	0.249
Myristic acid (C 14:0)[2]	1.34	1.17	0.09	0.022
Palmitic acid (C 16:0)[2]	11.59	10.48	0.39	0.001
Margaric acid (C 17:0)[2]	0.33	0.31	0.03	0.375
Stearic acid (C 18:0)[2]	2.75	2.91	0.12	0.059
Total saturated fatty acid[2]	69.9	64.1	0.47	0.001
Oleic acid (C 18:1n-9)[2]	12.1	18.5	0.34	0.001
Total monounsaturated fatty acid[2]	13.8	20.6	0.39	0.001
Linoleic acid (C 18:2n-6)[2]	12.5	11.1	0.62	0.007
α-Linolenic acid (C 18:3n-3)[2]	3.2	3.6	0.26	0.032
EPA (C 20:5n-3)[2]	0.01	0.07	0.004	0.001
Total polyunsaturated fatty acid[2]	16.30	15.30	0.62	0.030
Output				
Milk (g / kg live weight / d)	61	71	10	0.029
Fat (g / kg live weight / d)	8.1	10.2	1.4	0.003
Protein (g / kg live weight / d)	6.3	6.3	1.0	0.926

[1]root mean square error (n=5 does per group). [2]% of total fatty acids.

A significantly lower short-chain FA content was observed in milk of the does fed the LL diet, probably associated with both the FA *de novo* synthesis, and the lower C 16:0 and the higher C 18:1n-

9 content in the LL diet when compared to the SL diet. Short-chain FA are synthesized within mammary gland (Maertens *et al*., 2006). In ruminant mammary gland cells, Hansen and Knudsen (1987) showed that C 16:0 addition to the incubation medium strongly stimulated synthesis and incorporation of FA synthesized *de novo* into triacylglycerols, whereas C 18:1n-9 was inhibitory. The LL diet led to a significantly higher C 18:3n-3 content in milk, a finding which can be explained by a lower C 18:2n-6/C 18:3n-3 ratio in the LL diet.

Data on the growth performance of litters before and after weaning are not presented in tables. Live weight of litters at beginning of the experiment and at the weaning, weight gain during the entire suckling period or solid feed intake between 22 and 30 day of age were not significantly affected by dietary treatment. However, between 1 and 21 day of the suckling period, litters of the rabbit does which were fed the LL diet showed higher weight gain (13.9 *vs.* 12.5 g/d, P=0.072) and better milk conversion ratio (1.96 *vs.* 2.04, P=0.048). There was no mortality of kits before weaning. During the entire fattening period (30 – 72 day of age), weight gain, feed intake, feed conversion ratio or live weight at the end of the experiment were not affected by dietary treatment. However, health risk index (sum of mortality and morbidity) was significantly lower in rabbits fed the weaning diet based on white lupin than in those fed the diet based on soybean meal (3.0% *vs* 16.7%, P=0.016). These rabbits also received milk with the higher C 18:3n-3 and C 20:5n-3 content. Similarly, Maertens *et al*. (2005), when studied the effect of a diet rich in n-3 polyunsaturated fatty acid (PUFA) on the performance and milk composition of the does and the viability of their litters, observed the significantly lower mortality in the n-3 PUFA fed rabbits after weaning.

CONCLUSION

It can be concluded that whole white lupin (*L. albus* cv. Amiga) seeds is a suitable protein source for lactating rabbit does. The diet based on whole white lupin led to higher milk yield, milk fat output per kg live weight, C 18:3n-3 and C 20:5n-3 content in milk.

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REFERENCES

AOAC. 1984. Official methods of analysis of the Association of Official Analytical Chemists, 14th edition. Washington, DC.

Bettzieche A., Brandsch C., Eder K., Stangl G. I. 2009. Lupin protein acts hypocholesterolemic and increases milk fat content in lactating rats by influencing the expression of genes involved in cholesterol homeostasis and triglyceride synthesis. *Mol. Nutr. Food Res., 53, 1134-1142.*

Hansen H.O., Knudsen J. 1987. Effect of exogenous long-chain fatty acids on individual fatty acid synthesis by dispersed ruminant mammary gland cells. *J. Dairy Sci., 70, 1350-1354.*

Maertens L., Perez J.M., Villamide M., Cervera C., Gidenne T., Xiccato G. 2002. Nutritive value of raw materials for rabbits: EGRAN Tables 2002. *World Rabbit Sci., 10, 157-166.*

Maertens L., Aerts J.M., De Brabander D.L. 2005. Effet d'un aliment riche en acides gras omega-3 sur les performances et la composition du lait des lapines et la viabilité de leur descendance. *In Proc. 11émes Journées de la Recherche Cunicole, 29-30 novembre, Paris, 205-208.*

Maertens L., Lebas F., Szendrö Zs. 2006. Rabbit milk : a review of quantity, quality and non-dietary affecting factors. *World Rabbit Sci., 14, 205-230.*

Pascual J.J., Cervera C., Blas E., Fernández-Carmona J. 2003. High-energy diets for reproductive rabbit does: effect of energy source. *Nutrition Abstracts and Reviews, 73 (5), 27R-39R.*

SAS., 2001. SAS/STAT User's Guide (Release 8.2). *SAS Inst. Inc., Cary, NC, USA.*

Volek Z., Marounek M. 2009. Whole white lupin (*Lupinus albus* cv. Amiga) seeds as a source of protein for growing-fattening rabbits. *Anim. Feed Sci. Technol., 152, 322-329.*

Volek Z., Marounek M. 2011. Effect of feeding growing-fattening rabbits a diet supplemented with whole white lupin (*Lupinus albus* cv. Amiga) seeds on fatty acid composition and indexes related to human health in hind leg meat and perirenal fat. *Meat Sci., 87, 40-45.*