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THE EFFECTS OF THE COMPLETE REPLACEMENT OF BARLEY AND SOYBEAN MEAL WITH HARD WHEAT BY-PRODUCTS ON DIET DIGESTIBILITY, GROWTH AND SLAUGHTER TRAITS OF A LOCAL ALGERIAN RABBIT POPULATION

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ABSTRACT: Eighty one rabbits were used to study the utilisation of hard wheat by-products on the growth of rabbits from a local Algerian population. At weaning (28 d, 501±99 g), the animals were individually caged and received *ad libitum* one of the three experimental diets for 49 d. The control diet included 26% wheat bran (W26: control diet), alfalfa, barley and soybean meal. The two other diets were formulated by substituting barley and soybean meal with hard wheat by-products, and contained 60% (W60) or 67% (W67) of these by-products (50 or 57% bran and 10% middling). On average, diets contained 11.8% crude fibre and crude protein decreased from 18.3 (W26) to 16.1% (W67). Growth traits and slaughter performances were recorded. Another group of thirty animals was used to determine dietary nutrient digestibility from 42 to 46 d of age. Dry matter digestibility and digestible energy content were lower in the W60 and W67 diets than in the control diet (W26) (71.3 and 71.5% vs. 74.9%, and 11.9 and 11.9 vs. 12.5 MJ/kg, respectively; $P<0.01$). In contrast, crude fibre digestibility was lower in W26 (21.9%) than in the other two diets (29.6 and 32.2% for W60 and W67, respectively; $P<0.01$). The growth rates were similar for all three groups (28.0, 27.1 and 26.0 g/d for W26, W60 and W67) as were the feed conversion ratios (3.14, 3.17 and 3.10, respectively). Dressing out percentage (66.4±2.0% on average for the cold carcass) was not affected by the amount of wheat by-products in the diet. The total mortality rate was high (23%), probably corresponding to the low crude fibre content of the three experimental diets, but was not connected to the amount of wheat by-products.

Key words: rabbit, hard wheat by-products, digestibility, growth performance, slaughter traits.

INTRODUCTION

Rabbit production is a propitious activity in Algeria. Over recent years, several initiatives have been carried out in order to develop this type of meat production. This has been of value to the local population. However, the high price of feed is the most discouraging problem encountered by breeders. For several years our laboratory has been working to formulate a balanced feed by using the maximum amount possible of locally available inexpensive raw materials (Berchiche and Lebas, 1990; Berchiche *et al.*, 1996 and 1999). Among these raw materials, wheat by-products seem to be of particular interest for the Algerian situation.

Algerians are among the largest wheat consumers in the world. Consequently, this results in appreciable quantities of wheat by-products left over by this industry. These locally produced by-products are generally employed as feed concentrate for ruminants. According to Villamide *et al.* (1989), it can be an inexpensive feed source with easy handling and storing capabilities for rabbit farming. In addition, its relatively high crude protein content, ranging from 12 to 18%, makes it attractive for protein deficient diets. Recently, Lebas (2004) emphasized that up to 40-50% of these cereal by-products can clearly be utilized.

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In a previous study, Berchiche *et al.* (2000) incorporated wheat bran and middling, which accounted for 50% of the feed mix without detecting any significant deterioration in growth performance.

The aim of this current research was to study the inclusion of a higher proportion (up to 2/3 of the diet) of hard wheat by-products (middling and bran) in the diets of a local population of rabbits from Algeria, regardless of whether these diets were completely balanced or not, and to estimate the effects on digestibility, health, growth and slaughter performances.

MATERIAL AND METHODS

Diets

Three pelleted diets based on wheat by-products were formulated. The control diet partly consisting of 26% hard wheat bran (W26), alfalfa, barley and soybean meal (Table 1), was a classical formula used in Algeria as a mixed diet for rabbit production. The other two experimental diets contained 10% hard wheat middlings and 50 or 57% hard wheat bran (W60 and W67), introduced mainly in place of barley and soybean meal. The three experimental diets were formulated using feedstuff composition tables (INRA, 1989) in order to guarantee the highest possible level of wheat by-products (hard wheat bran + middling). The target composition for diets was $16.5 \pm 1\%$ crude proteins and approximately 13.5% crude fibre. The accepted modification of the nutritive value resulted in a concomitant reduction in proteins and digestible energy alongside an increase in wheat by-products, in order to maintain a constant protein to energy ratio. The list of ingredients and the chemical composition of the experimental diets are given in Table 1.

Animals and experimental design

Eighty one mixed-sex rabbits from a local Algerian population (Lakabi *et al.*, 2004; Zerrouki *et al.*, 2004, 2005, 2007) weaned at 28 d of age and weighing 501 ± 72 g (mean \pm 1 SD) were assigned to the three experimental groups (27 rabbits/diet) according to weaning weight and litter origin. Rabbits were housed in individual wire mesh cages arranged in flat deck disposition and were fed the experimental diets *ad libitum* (without any transition period from mother's diet to experimental diet) from weaning to the end of the experiment at 11 weeks of age. There was a constant supply of fresh water. Live weight and feed consumption were controlled weekly, and mortality was controlled daily. Growth traits were calculated only for those rabbits alive at the end of the experiment. Rabbit cages were installed in one of the rooms of the Tizi Ouzou University facilities during the spring months. Temperature was not artificially controlled and varied between 18 and 25°C. Humidity was not measured. Artificial light was programmed at 7 h light/24 h.

At the end of the trial (at 11 weeks of age), rabbits were slaughtered in order to measure skin, full digestive tract, hot carcass weight, liver, kidneys and abdominal fat in accordance with Blasco *et al.* (1993), albeit with one noticeable difference, that the skin was not removed from the head, thus adhering to the local market tradition. Cold carcasses (24 h at +4°C) were presented with heads (unskinned), thoracic content (heart, lungs), liver, kidneys and the extremities of each of the 4 legs (feet) with skin, also in accordance with the local market tradition. Dressing out percentages were calculated for both the hot and cold carcass presentations. The relative weight of liver, kidneys and abdominal fat was expressed as a percentage of the cold carcass.

The nutrient digestibility of the three diets was measured according to the European Reference Method (Perez *et al.*, 1995) using 3×10 additional local rabbits weaned at 28 d of age and weighing 481 ± 53 g. Faeces samples were collected between 42 and 46 d of age and were stored at -18°C until treatment for analysis.

Table 1: Percentage of ingredients and chemical composition of the experimental diets.

Ingredients %	Diets		
	W26	W60	W67
Soya meal 44	12	4	-
Dehydrated alfalfa	36	35	32
Hard wheat bran	26	50	57
Hard wheat middlings	-	10	10
Barley	25	-	-
Mineral and vitamins	1	1	1
Chemical composition, % as fed			
Dry matter	89.2	89.3	89.1
Crude protein	18.3	17.4	16.1
Crude fibre	11.1	12.7	11.7
Ash	7.4	7.7	7.0
Calculated SAA	0.58	0.57	0.55
Calculated Lysine	0.85	0.74	0.65
Gross Energy (MJ /kg)	16.5	16.7	16.6

SAA: sulphur amino-acids – SAA and lysine levels calculated according to INRA (1989).

Chemical analyses

All the analyses were conducted at the Station de Recherches Cunicoles (INRA Research Centre, Castanet Tolosan, France). The following chemical analyses were carried out on feed and faeces according to AOAC (1984): dry matter (24 h at 103°C), ash (5 h at 550°C), gross energy (using a Parr adiabatic calorimeter, Moline, Illinois, USA), and crude fibre (the Weende method). Nitrogen was determined in accordance with the Dumas combustion method using a Leco auto-analyzer (model FP-428, Leco Corp., St Joseph, MI, USA) and converted to crude protein using the factor 6.25.

Statistical analyses

Analyses of data were carried out using variance analysis with the Statistical Analysis System (SAS Version 6.1, SAS Institute Inc., Cary, USA; 1987) employing the general linear model (GLM procedure). For digestibility results, only the experimental treatment was included as a control factor. For the growth performance study, to begin with the experimental diet, litter origin and rabbit sex were used as fixed effects with the corresponding 2×2 interactions. The different interactions between factors were not significant and hence were excluded from the model. Sex initially included as a third control factor was not significant for any of the studied growth parameters. Therefore, it was removed from the final model, which subsequently included only diet and litter as control factors together with the initial weight as a co-variable. For slaughter data, rabbit sex was added as an additional control factor to the two previously mentioned. When the treatment effect was significant ($P < 0.05$), differences between means were determined using the Duncan Test or by introducing adequate contrasts in the computation of variance analysis (SAS, 1987).

RESULTS AND DISCUSSION

Nutritional composition of diets

The analytical composition of the three diets (Table 1) was higher than expected for crude protein (on average 17.4% instead of the expected 16.5%) and lower for the crude fibre level (on average 11.8% instead of the expected 13.5%). However, the calculated hierarchy between diets was not modified. This difference between the expected and the observed compositions was most probably due to the utilisation of dehydrated alfalfa containing a higher than expected protein content: 18.5% instead of the classical 16.5% crude protein level. The inclusion of this high protein type of alfalfa in the calculated composition of the three diets gives an estimation which closely resembles the analytical results. Thus this hypothesis can be accepted. As a consequence, the calculated levels for lysine and sulphur amino acids (SAA) in the three diets presented in Table 1, must be upgraded to 1.02, 0.96 and 0.88% of the diet for the lysine levels, and by up to 0.61, 0.58 and 0.55% of the diet for the SAA levels in diets W26, W60 and W67 respectively.

Following this correction, it appears that the proteins in the 3 diets (W26, W60 and W67) contained similar proportions of lysine (5.57, 5.49 and 5.42%) and SAA (3.34, 3.31 and 3.35%). The lysine proportion in the proteins was a little over 5.05%, the level recommended by various authors (De Blas and Mateos, 1998; Lebas 2004). In fact, the complete elimination of soybean meal in diet W67 has not resulted in any lysine deficiency as it may have been feared. For SAA, the concentration in proteins was lower than the generally accepted recommended value of 3.75% (De Blas and Mateos, 1998; Lebas 2004), but was homogenous for the three experimental diets. Nevertheless, this level still falls within the safety zone, where various authors have previously situated the optimum level for SAA ever since the very first proposition established by Adamson and Fisher (1973). A more valid point for the present comparison is the fact that the SAA level was homogenous for the three experimental diets. Consequently, possible variations in growth performances between treatments could not be attributed to a difference in the SAA supply.

It must be pointed out that where the three diets were not isonitrogenous, their crude fibre level was similar.

As anticipated, the substitution of wheat by-products for barley and soybean meal generated a significant reduction in dry matter and energy digestibility (Table 2) and a significant improvement in crude fibre digestibility. This is an expected consequence of the reduction in the diet starch level (the removal of barley between diets W26 and W60) and the increase in digestible fibre parts in the determination of

Table 2: Digestibility coefficient of the three experimental diets (10 rabbits/treatment).

Digestibility coefficient	Treatments (Diet)			Residual standard deviation	P-value
	W26	W60	W67		
Dry matter	74.9 ^a	71.3 ^b	71.5 ^b	2.8	<0.01
Crude proteins (CP)	84.2	83.0	84.4	1.8	0.16
Crude fibre	21.9 ^a	29.6 ^b	32.2 ^b	7.9	<0.01
Energy	75.9 ^a	71.1 ^b	71.7 ^b	3.0	<0.01
Digestible energy MJ/kg (DE)	12.5	11.9	11.9	-	-
Digestible protein g/kg (DP)	154	144	136	-	-
Ratio DP/DE g/MJ	12.3	12.2	11.4	-	-

Means within a row with different superscripts differ. ($P=0.05$).

crude fibre with wheat bran inclusion, leading to the high crude fibre digestibility of these wheat by-product as previously outlined by Maertens and Van Herck (2001). This reduction in dry matter or energy digestibility with the introduction of wheat bran satisfactorily concurred with the accepted energy values for wheat bran, barley and soybean meal: 2460, 3030 and 3270 kcal/kg as published by Sauvant *et al.* (2002). No significant variation in nitrogen digestibility was observed between diets as was expected from the known nitrogen digestibility of the raw materials used for the substitution (Sauvant *et al.*, 2002).

It could be pointed out that the average protein digestibility in this experiment (83.9%) was at the same level as that observed some years earlier (on average 83.5%) by Berchiche *et al.* (2000) in the same laboratory with diets containing 53 to 56% of hard wheat by-products.

However, the digestible protein level (DP) in the three diets (ranging from 13.6 to 15.4%) is above the values considered to be acceptable for mixed rabbit feeds: 10.8% according to De Blas and Mateos (1998) or 11.0-12.5% according to Lebas (2004). In contrast, the crude fibre level in the three diets was under 13%, a value lower than that actually recommended for growing rabbits (15-16% according to De Blas and Mateos, 1998).

The digestible energy (DE) content of the three diets (11.9- 12.5 MJ/kg) was clearly above the classical minimum recommendations for mixed diets (9.5 MJ/kg recommended by Lebas, 2004). However, the DP/DE ratio positively reflected the recommended level (11.4-12.3 g/MJ for a recommendation of 11.5-12.0). With regards to the composition of the three experimental diets, this study concludes that these were more concentrated than recommended, but correctly balanced from a nutritional point of view (protein/ energy ratio and protein composition). Nevertheless, the low level of crude fibre and the high digestible protein levels may be a source of digestive risks (Gidenne, 2000; Gutiérrez *et al.*, 2003).

Health and growth performance

The average mortality rate during the whole experiment (28 to 77 d of age) was 23.5%: 5, 7 and 7 rabbits died in the W26, W60 and W67 groups, respectively. Mortality, due to diarrhoea, occurred only during the second and third weeks of the experiment. This situation is likely to be related to the previously mentioned deficiency in fibre, reinforced by the protein excess of these diets as pointed out by Lebas *et al.* (1998) or Gidenne (2000). Subsequently, at the end of the experiment, all calculations were made using the surviving rabbits. It could be pointed out that mortality did not alter the balance between the three treatments, nor the initial average weight of the rabbits: 502.7g for those alive at the end vs. 500.7 for the 81 initial rabbits.

The average daily growth (27.0 g/d) was similar in the three groups (Table 3) and approached the best results obtained under our conditions using this population (Berchiche *et al.*, 1999, Berchiche and Kadi, 2002, Kadi *et al.* 2004., Lakabi *et al.*, 2004). It should be stressed that this growth rate corresponds to a relative daily increase representing 0.96% of the adult weight (27 g for an adult weight of 2810 g according to Zerrouki *et al.*, 2004). This proportion is similar to and even a little bit higher than that obtained with selected hybrid lines with an adult weight of between 4.8 and 5.0 kg [the average weight of males and females, according to Rochambeau *et al.* (1996) for males and Theau-Clément and Fortun-Lamothe (2005) for females], increasing by 45-46 g/d, which corresponds to a relative daily increase of 0.93-0.94%. For this reason, it can be assumed that the average composition of the experimental diets was not a limiting factor in the growth rate of rabbits from this local Algerian population.

The numerical reduction in feed intake observed between the first two diets W26, W60 and diet W67 was insignificant ($P=0.129$). Nevertheless, if the contrast between the first two diets and W67 is calculated, a clear trend towards a reduction can be demonstrated ($P=0.074$). However, the experimental treatments had no significant effect on feed efficiency, which was highly homogenous for the three diets

Table 3: Growth rate and feed intake during the fattening period. Arithmetic means for initial weight, and least square means for other criteria (initial weight used as a covariate for the final weight; $P < 0.01$).

	Treatments (Diet)			Residual standard deviation ⁽¹⁾	P-value
	W26	W60	W67		
Rabbits/treatment	22	20	20	-	-
Initial weight, g	503	512	493	55	0.464
Final weight, g	1878	1835	1787	197	0.268
Average daily gain, g/d	27.98	27.09	26.01	3.79	0.385
Feed intake, g/d	87.9	86.1	80.8	12.7	0.129
Feed conversion ratio	3.14	3.17	3.10	0.20	0.363

⁽¹⁾ Residual standard deviation; factors included in the statistical model: treatment, litter origin and, except for initial weight, weaning weight as a covariate.

(3.10 to 3.17), despite the previously mentioned differences in nutritive value. The most probable explanation for the absence of significant differences between growth performances observed in the three treatments is that the control diet was highly concentrated. Subsequently, the reduction in concentration as a result of the introduction of wheat by-products in place of barley and soybean meal was not sufficient to cause any nutritional imbalance capable of affecting the growth rate or feed efficiency.

Slaughter performances

As stated earlier in the material and methods section, the rabbit heads were not skinned. According to the results published by Rochambeau *et al.* (1996), it can be assumed that the weight of a skinless head is approximately 95-100 g for a carcass of 1.2 kg. A proportion of 15-18% of skin for the unskinned head can be considered as normal, corresponding to an estimated weight of 14-15 g for the skin remaining on the head with regards to our local presentation of carcasses. Hence, the incidence of this non-standard presentation is then approximately 0.7-0.9 point, i.e. less than 1 point of the slaughter rate, or of the total skin proportion. Thus, in order to compare our results and those of the literature, the slaughter rates obtained in the present study should be reduced by 1 point and the relative weight of the skin increased by 1 point.

Regardless of the presentation, the incorporation of dietary wheat bran by-products did not affect the carcass weight (Table 4). The increase in the proportion of wheat by-products (together with the concomitant reduction in barley and soybean meal) led to a significant ($P=0.022$) increase in the proportion of the full digestive tract as a percentage of live weight, from 15.7% at slaughter live weight (SW) for W26 rabbits to 17.3% SW for W67 rabbits. This increase may be related to the higher proportion of total fibre. In effect, the total fibre estimated through the calculated values for NDF was 31% for W26 diets and 36% and 38% for the W60 and W67 diets respectively. The influence of dietary fibre level on the contents of the digestive tract has been effectively underlined for quite some time without the need to modify the slaughter rate (Ouhayoun *et al.*, 1986). In the present case, this increase in the full digestive tract induced a numerical alteration of the slaughter rate. This reduction borders on being significant for the hot carcass proportion (a reduction in slaughter rate by 1.4 points between W26 and W67; $P=0.063$), but becomes insignificant for the cold carcass presentation ($P=0.161$). The proportions of liver, kidneys or abdominal fat were not affected by the incorporation of wheat by-products.

With the local population used in this study, the average slaughter rate calculated after removing the lower extremities from the cold carcass was 63.48%, without any significant difference between treatments ($P=0.192$). After making the adjustments for head skinning as proposed above, this corresponds to a

Table 4: Slaughter performances of rabbits (least square means; 20 rabbits/treatment).

	Treatments (Diet)			Sex		Resid CV ¹	<i>P</i> -value	
	W26	W60	W67	F	M		Diet	Sex
Slaughter weight (SW), g	1873	1851	1772	1853	1821	207	0.291	0.408
Hot carcass g (HC), g	1315	1282	1222	1280	1266	162	0.195	0.768
Cold carcass (CC), g	1252	1223	1165	69.0	70.1	159	0.232	0.782
Slaughter rate HC/SW, %	70.2	69.6	68.8	65.5	66.8	1.8	0.063	0.031
Slaughter rate CC/SW, %	66.8	66.4	65.6	10.2	9.8	2.0	0.161	0.039
Skin, % SW	10.0	10.0	9.8	10.2	9.8	0.7	0.644	0.048
Digestive tract, % SW	15.7 ^a	16.1 ^{ab}	17.3 ^b	16.8	15.9	1.8	0.022	0.115
Liver, % CC	7.09	7.35	7.33	6.89	7.62	1.06	0.702	0.024
Kidneys, % CC	1.25	1.22	1.18	1.21	1.21	0.15	0.355	0.945
Abdominal fat, % CC	1.85	2.01	1.97	2.08	1.80	0.51	0.602	0.063

¹Residual coefficient of variation, factors included in the statistical model: treatment, litter origin and sex. Means within a row and factor with different superscripts differ. ($P=0.05$).

dressing percentage of approximately 62.5%. This is substantially higher than the 55-58% observed by Lebas *et al.* (2001) for selected European lines slaughtered between the ages of 10 and 14 weeks, or the average dressing of 53 to 57% as described by Rochambeau *et al.* (1996) for commercial strains slaughtered between 8 and 14 weeks, with the same standard carcass presentation. The very high dressing percentage for rabbits from this local population was still stressed by Lakabi *et al.* (2004) for animals slaughtered at 15 weeks. This very high slaughter rate is one of the consequences of the low proportion of raw skin (approximately 11% following head skinning adjustment) in comparison with the 14.5 to 16.0% mentioned by Rochambeau *et al.* (1996). The characteristics of this population may be a direct consequence of adapting to the relatively hot climate found in Algeria, as suggested some years ago by Lebas and Ouhayoun (1987) after studying the effects of the rearing season.

In the model for the statistical analysis of slaughter traits, the sex of rabbits was introduced as a control factor (Table 4). It could be pointed out that the female dressing percentage is lower than that of the male: 69.0 vs. 70.1% for hot carcasses ($P=0.031$). This is partly due to a higher skin proportion: 10.2 vs. 9.8 ($P=0.048$). Females also displayed a relatively lighter liver weight (6.89% vs. 7.62% of carcass; $P=0.024$) and tended to be fatter (2.08% vs. 1.80% of abdominal fat in the carcass; $P=0.065$). These trends were not observed in our previous study of rabbits from this population slaughtered at 15 weeks (Lakabi *et al.*, 2004), except for the lighter liver weight of the females. In contrast, greater fat levels for females, as observed in this study, are generally accepted (Ouhayoun, 1989, Dalle Zotte, 2002).

CONCLUSION

The present results suggest that the high incorporation rate of wheat by-products in the diet of growing rabbits (60 to 67%), totally substituting barley and soybean meal, neither modifies the growth traits nor the slaughter performances of rabbits belonging to a local Algerian population, despite the reductions in dry matter and energy, two coefficients of digestibility. Nevertheless, new experiments involving diets with a high incorporation rate of wheat by-products and following the current recommendations for fibre are necessary.

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