Proceedings 5th World Rabbit Congress, 25-30 July 1992, Corvallis – USA, 1008-1016.

SUBSTITUTION OF BARLEY GRAIN BY SUGAR-BEET PULP IN DIETS FOR FINISHING RABBITS.1. EFFECT ON ENERGY AND NITROGEN BALANCE

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Abstract

One hundred and five New Zealand x California weanling rabbits were used to study the influence of increasing dietary content of digestible fiber replacing starch on feed efficiency and body composition. Three diets, formulated by substituting barley grain with sugar-beet pulp (SBP), and two slaughter weights (2 or 2.5 kg) were used in a 2 x 3 factorial arrangement. Energy digestibility decreased linearly ($P < .001$), although NDF and crude fiber digestibilities increased ($P < .01$), with substitution of barley by SBP. From these results, a DE value of 2400 kcal/kg DM for SBP was calculated by difference. Increasing dietary digestible fiber level or lowering slaughter weight also led to significant changes in body composition, with higher proportion of water, ash and protein, and lower of fat and energy content. Neither type of diet nor slaughter weight affected significantly daily DM intake per $kg^{.75}$. Both DE and digestible CP efficiencies for growth were impaired with level of inclusion of SBP; differences were higher when proportion of SBP in the diet increased from 15 to 30 than from 0 to 15%. Stepwise regression analysis showed that digestible NDF intake was the variable better related both to energy and nitrogen effciencies. Slaughter weight did not affect intake or energy efficiency, but protein retention and protein efficiency were lower ($P < .001$) for rabbits slaughtered at the heaviest weight. Interaction diet x slaughter weight had little effect on most of the traits studied.

Introduction

Sugar-beet pulp (SBP) is mainly used in rabbits as a concentrate of energy (according to its content in high digestible fiber, pectins and sugars) and so as an alternative to the inclusion of cereal grains and starch in the diet.

Digestible energy (DE) value of SBP has been determined previously by giving pulps as the only rabbit feed (Martinez and Fernandez, 1980) or by substitution of a basal diet (Maertens and de Groote, 1984; Fekete and Gippert, 1986). Nevertheless these methods have proven to be inaccurate for SBP, because its digestion is affected both by level of inclusion and basal diet composition, (de Blas and Villamide, 1990; Garcia et al, 1992). Furthermore, previous work in rabbits (Garcia et al, 1992) showed that increasing dietary digestible fiber content decreased efficiency of conversion of DE for growth; consequently, use of DE instead of NE would overestimate SBP energy value.

The aim of this study has been to determine the energy and nitrogen value of SBP in relation to barley grain in diets with higher content of indigestible fiber than used previously (Garcia et al, 1992).

Material and Methods

Diets. A barley-based control diet (30% barley grain, 20% ADF) was formulated to meet all the essential nutrient requirements for growing rabbits according to Lebas (1980) and de Blas et al. (1981). Another two experimental diets were made by substituting partial or totally barley grain by SBP, the proportions of the other ingredients remaining constant. Dietary designations, based on the ratios of as-fed proportions of barley and SBP were the following: 30:0, 15:15 and 0:30. The chemical analysis of barley grain and SBP are presented in Table 1; ingredient composition and chemical analysis of the diets are shown in Table 2.

TABLE 1. CHEMICAL COMPOSITION OF SUGAR-BEET PULP AND BARLEY GRAIN (%, DM basis)

Item	Sugar-beet pulp	Barley grain
DM	90.2	89.7
Ash	6.2	2.4
CP	9.3	10.9
Starch	2.3	55.5
Crude fiber	22.7	4.2
ADF	27.6	6.4
NDF	59.7	31.5
ADL	2.0	1.6
GE, kcal/kg of DM	4110	4391

Growth Trial. The three experimental diets and two slaughter weights (2 and 2.5 kg) were used in a 3 x 2 factorial arrangement. Sixty male and female New Zealand White x California rabbits were assigned to treatments at random with ten replicates per each treatment combination. Rabbits were weaned at 30 d and were given *ad libitum* access to feed until they reached the preestablished slaughter weight. Feed intake and growth rate were registered individually. Animals were slaughtered by cervical dislocation. After manual extraction of digestive content, empty bodies were frozen at -20° C, then ground and homogenized three consecutive times, alternating grinding and freezing each time, to obtain representative samples for body composition analysis. Protein, fat, and energy content at weaning were estimated from weaning weight, using equations developed by Motta (1990) in similar breeding conditions.

Digestibility Trial. Another group of 45 male and female New Zealand x California rabbits (15 per diet) weighing from 1.6 to 1.8 kg were alloted at random to the four diets. Following a 14-d period of adaptation to each diet, animals were housed in metabolism cages that allowed separation of feces and urine. Collections were made on four consecutive days; feces produced daily were collected in labelled polyethilene bags and stored at

TABLE 2. INGREDIENT AND CHEMICAL COMPOSITION OF THE EXPERIMENTAL DIETS

	Barley:SBP[a], %		
Item	30:0	15:15	0:30
Ingredient, %			
Barley grain	30.0	15.0	-
Sugar-beet pulp	-	15.0	30.0
Alfalfa hay	58.2	58.2	58.2
Soybean meal	11.0	11.0	11.0
Sodium chloride	.5	.5	.5
Vitamin/mineral mix[b]	.2	.2	.2
Chemical analysis, % DM			
Ash	8.7	9.2	9.5
CP	19.2	18.9	19.2
Starch	17.0	9.1	2.2
Crude fiber	18.6	20.8	24.0
ADF	22.8	25.9	28.0
NDF	39.6	43.6	47.4
ADL	5.5	5.6	5.8
GE, kcal/kg of DM	4284	4240	4228

[a] SBP = Sugar-beet pulp.

[b] Provided by Cyanamid Iberica. Mineral and vitamin composition (g/kg): Mn, 7.5; Zn, 25; I, .5; Fe, 20; Cu, 2.5; Co, .2; Se, .03; riboflavin, 1.25; calcium pantothenate, 4; nicotinic acid, 7.5; choline chloride, 25; vitamin K_3, .25; vitamin E, 6; vitamin A, 3,750,000 IU/kg; vitamin D_3, 900,000 IU/kg.

-20° C.

Housing. During both trials rabbits were kept in a closed building with partial environmental control. Temperature during the experimental period ranged from 16 to 20° C. A cycle of 16 h light and 8 h dark was used throughout the experiment.

Analytical Methods. Chemical analysis of diets, feces and animals were made following the method of Van Soest (1963) for ADF and ADL, Robertson and Van Soest (1977) for NDF, E.E.C. (1972) for starch, and A.O.A.C. (1984) for DM, ash, CP, ether extract and crude fiber. Gross energy was determined by adiabatic bomb calorimetry.

Statistical Analysis. Data were analysed using the ANOVA procedure of SAS (1985) with type of diet and slaughter weight as main sources of variation. Tests for differences among diets were made using a t-test. Stepwise regression analysis was used to develop equations for predicting energy and nitrogen efficiency.

Results and Discussion

Digestibility. The effect of type of diet on nutrient digestibility is shown in Table 3. The substitution of barley grain by SBP implied a decrease of energy ($P < .001$) and nitrogen ($P < .05$) and an increase ($P < .01$) of NDF and crude fiber digestibilities.

TABLE 3. EFFECT OF LEVEL OF SUBSTITUTION OF BARLEY GRAIN BY SBP[a] ON NUTRIENT APPARENT DIGESTIBILITY (%)

	Barley:SBP[a], %				
Item	30:0	15:15	0:30	SE[b]	P
DM	64.8^{x}	61.7^{xy}	58.8^{y}	1.25	.001
OM	64.8^{x}	61.5^{y}	58.3^{z}	1.03	.001
Energy	62.2^{x}	58.4^{y}	55.1^{z}	1.02	.001
CP	74.6^{x}	72.8^{y}	72.3^{y}	.90	.05
ADF	31.9	34.5	33.9	1.70	NS
NDF	44.5^{x}	45.2^{x}	48.2^{y}	1.15	.01
Crude fiber	27.8^{x}	30.4^{x}	35.1^{y}	2.02	.01

[a] SBP = Sugar-beet pulp.
[b] SE = Standard error of treatment means, n = 15.
[x,y,z] Means within a row lacking a common superscript differ ($P < .05$)

Digestible energy contents for diets 30:0; 15:15, and 0:30 were 2665, 2476 and 2330 kcal/kg DM, respectively. According to this, substitution of 15 and 30% of barley grain by SBP decreased dietary DE content by 1134 and 1005 kcal/kg, on a 100% substitution basis; assuming a DE value for barley grain of 3200 kcal/kg (Maertens et al., 1990; Villamide and de Blas, 1991), the corresponding DE values for SBP, calculated by difference, were 2066 and 2195 kcal/kg (i.e., 64.5 and 68.5% of that of barley grain). These values are lower than those obtained previously with diets containing lower levels of indigestible fiber (de Blas and

Villamide, 1990; Garcia et al, 1992) or higher levels of inclusion of SBP (Martinez and Fernandez, 1980; Maertens and de Groote, 1984; Fekete and Gippert, 1986), but similar to that obtained (2.17 kcal DE/kg) by substitution of a low-energy density basal diet (de Blas and Villamide, 1990). The variations observed between the different studies could be probably explained by differences in the amount of NDF reaching the cecum and in cecal fermentation time, as dietary NDF digestibilities varied following a similar pattern to DE of SBP.

According to these and previous results (Garcia et al., 1992) a DE value around 2150 or 2300 kcal/kg (equivalent to 2400 or 2550 kcal/kg DM) should be assigned to SBP, when replacing a moderate proportion of cereal grain at dietary levels of indigestible ADF of about 17 or 13%, respectively.

Body Composition. Type of diet and slaughter weight had a highly significant influence on body composition (Table 4). Both substitution of barley grain by SBP and a lower slaughter weight implied a decrease of DM, fat and energy and an increase of protein and ash contents in empty body. The largest differences were found for fat content, which decreased by 22% when dietary proportion of SBP increased from 0 to 30%, and increased by 12.5% when slaughter weight increased from 2 to 2.5 kg. No significant interaction between diet and slaughter weight were found for any of the components studied.

The effect of diet was greater than that observed for a similar increase in dietary fiber content, when diets were based on traditional (and more lignified) sources of fiber as alfalfa hay, grass meal, wheat bran or wheat straw (Fraga et al., 1983; Partridge et al., 1989). Relative decreases of fat and energy content were also higher than those obtained for inclusion of SBP in diets with lower indigestible fiber content (Garcia et al., 1992).

Table 4 also shows that energy content of live weight gain decreased linearly with SBP inclusion (by 23.5 % between extreme diets) and increased with slaughter weight (by 12.7%), whereas CP content in live weight gain was not affected neither by diet nor by slaughter weight, averaging 17.55% (SD = ±1.34). Interaction diet x slaughter weight affected (P = .03) CP content, rabbits fed on diet 15:15 showing higher values when slaughtered at 2.5 than at 2 kg (18.0 vs 17.4%).

Energy and Nitrogen Balance. Although rabbits were able to maintain DM intake as SBP proportion in the diet increased (88 g per $kg^{.75}$ and day as average, see Table 5), DE intake and energy retention decreased (by 13 and 30% between extreme diets), as a consequence of the impairment of energy digestibility and of efficiency of conversion of DE for growth with dietary level of SBP, respectively. A similar reduction in DE efficiency has been reported both in rabbits (Garcia et al, 1992) and in growing pigs (Zhu et al, 1990) with increasing levels of dietary digestible fiber, and could be explained by higher energy losses related to cecal digestion (methane and fermentation heat) and by the lower efficiency of utilization of DE for energy retention as protein than as fat (de Blas et al, 1985; Partridge et al., 1989). An impairment of DE efficiency for growth has also been observed for

TABLE 4. EFFECT OF DIET COMPOSITION AND SLAUGHTER WEIGHT ON EMPTY BODY AND LIVE WT GAIN (LWG) CHEMICAL COMPOSITION

	Barley:SBP[a], %					Slaughter wt (kg)			
Item	30:0	15:15	0:30	SE[b]	P	2.0	2.5	SE[c]	P
Dry matter (%)	34.6^{x}	33.4^{y}	32.1^{z}	.39	.001	32.3	34.5	.32	.001
Ash (% of DM)	8.05^{x}	8.39^{x}	9.06^{y}	.21	.003	8.90	8.07	.17	.001
Crude Protein (% of DM)	56.6^{x}	57.9^{x}	60.8^{y}	.83	.002	60.0	56.7	.68	.001
(% of LWG)	17.8	17.7	17.2	.29	NS	17.8	17.3	.23	NS
Ether extract (% of DM)	32.4^{x}	29.7^{x}	25.3^{y}	1.10	.001	27.3	31.2	.91	.002
Energy (kcal/g DM)	6.43^{x}		6.02^{z}	.06	.001	6.14	6.34	.05	.004
(kcal/g wt gain)	2.21^{x}		1.79^{z}	.05	.001	1.89	2.13	.04	.001

[a] SBP = Sugar-beet pulp.

bSE = Standard error of treatment means for diet, n = 20.

[c] SE = Standard error of treatment means for slaughter wt, n = 40.

[x,y,z] Means within a row lacking a common superscript letter differ ($P < .05$)

TABLE 5. EFFECT OF DIET COMPOSITION AND SLAUGHTER WEIGHT ON ENERGY AND NITROGEN BALANCE (PER $kg^{.75}$ AND DAY) AND EFFICIENCY (%)

	Barley:SBP[a], %					Slaughter wt (kg)			
Item	30:0	15:15	0:30	SE[b]	P	2.0	2.5	SE[c]	P
DM intake (g)	86	88	92	.25	NS	89	88	.22	NS
DE intake (kcal)	229^{x}	218^{y}	214^{y}	4.9	.001	223	219	4.0	NS
Digestible CP intake (g)	12.2	12.1	12.8	.29	NS	12.5	12.3	.24	NS
Energy retention (kcal)	56.9^{x}	50.1^{y}	40.1^{z}	1.9	.001	49.5	48.7	1.5	NS
Protein retention (g)	4.64^{x}	4.39^{x}	3.82^{y}	.12	.001	4.63	3.93	.09	.001
Fat retention (g)	2.86^{x}	2.43^{x}	1.74^{y}	.15	.001	2.21	2.47	.12	NS
Energy efficiency for growth									
- Overall (kge)[d]	24.8^{x}	22.9^{x}	18.8^{y}	.74	.001	22.0	22.2	.61	NS
- Partial (kpe)[e]	54.0^{x}	53.3^{x}	44.6^{y}	1.2	.01	50.0	51.2	1.0	NS
Nitrogen efficiency for growth									
- Overall (kgn)[f]	36.1^{x}	35.9^{x}	31.4^{y}	1.0	.009	36.9	32.0	.81	.001
- Partial (kpn)[g]	53.2^{x}	53.3^{x}	45.9^{y}	1.7	.018	54.0	47.7	1.4	.007

[a] SBP = Sugar-beet pulp.

bSE = Standard error of treatment me r diet, n = 20.

[c] SE = Standard error of treatment means for slaughter wt, n = 40.

[d] kge = energy retention * 100/DE intake.

[e] kpe = energy retention * 100/(DE intake - 124).

[f] kgn = CP retention * 100/digestible CP intake.

[g] kpn = CP retention * 100/(digestible CP intake - 3.85).

[x,y,z] Means within a row lacking a common superscript letter differ ($P < .05$)

diets with a high proportion of indigestible fiber (de Blas et al., 1985; Partridge et al., 1989; Ortiz et al., 1989).

Protein retention and protein efficiency were impaired ($P < .001$) with inclusion of SBP and when rabbits were slaughtered at the heaviest weight. These effects could be explained by a deficit of NE supplied from carbohydrates and by a lower ability for protein synthesis in the later stages of the fattening period, respectively.

The effect of SBP inclusion on overall energy (kge) and nitrogen (kgn) efficiencies (%), was analysed using the stepwise regression procedure and data obtained in a previous work (Garcia et al., 1992). The variable which better explained the variation of both efficiencies was digestible NDF content in the diet ($R^2 = .90$ and .85, respectively). Accuracy of prediction was slightly improved when considering also DM intake. The regressions obtained were:

$$kge = 39.2\ (\pm\ 2.13) - .895\ (\pm\ .119)\ DNDFI;\ R^2 = .92;\ n = 7$$

$$kgn = 49.6\ (\pm\ 2.27) - .808\ (\pm\ .127)\ DNDFI;\ R^2 = .89;\ n = 7$$

, where DNDFI = digestible NDF intake (g/d)

Partial efficiencies of energy and nitrogen for growth were estimated assuming maintenance requirements of 124 kcal DE and 3.85 g digestible CP per $kg^{.75}$ and day (de Blas et al., 1985; Partridge et al, 1989; Ortiz et al, 1989; Motta et al, 1990). Although no significant differences were found between diets 30:0 and 15:15, both efficiencies decreased for diet 0:30 (Table 5), which implies that use of DE or digestible CP would overestimate nutritive value of SBP when its level of inclusion in the diet is high.

Interaction diet x slaughter weight did not affect any of the efficiency traits studied.

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