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Nutritional effects of barley application in monogastric feeding

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SUMMARY - The utilization of barley in monogastric diets, in particular, poultry and swine, is considered. The relationship between some analytical parameters and productive response in poultry is discussed. The improvement of barley with enzymes with ß-glucanase activity is also reviewed. Enzymes improve the efficiency of feed utilization and carcass yield, reduce the incidence of sticky droppings, the moisture of faeces and water consumption. These positive effects have been obtained in mash and pelleted diets. Barley can also be used at high levels in laying hen diets. ß-glucanase also show positive effects in laying hens, although to a lesser degree than in broilers. Barley is a very appropiate cereal for swine. The effects of processing and enzymatic supplementation in order to improve the digestibility of barley in weaning pigs are presented.

RESUME - "Effets nutritionnels de l'utilisation de l'orge pour l'alimentation des monogastriques". On présente l'utilisation de l'orge pour l'alimentation des monogastriques, en particulier pour les volailles et les porcins. La relation entre certains paramètres analytiques et la réponse du point de vue productif chez les volailles, est analysée. L'amélioration de l'orge avec des enzymes présentant une activité ß-glucanase est passée en revue. Les enzymes améliorent l'efficacité de l'utilisation de cet aliment et le rendement de la carcasse, et réduisent l'incidence des souillures causées par les fientes, en diminuant l'humidité des excréments et la consommation d'eau. Ces effets positifs ont été obtenus avec l'aliment hâché et granulé. L'orge peut aussi être utilisé en grandes proportions en alimentation des poules pondeuses. La ß-glucanase a aussi des effets positifs sur les poules pondeuses, quoiqu'à un degré moindre que chez les poulets de chair. L'orge est une céréale très adéquate pour les porcins. Les résultats du conditionnement et de la supplémentation enzymatique, en vue d'améliorer la digestibilité de l'orge pour les porcins, sont présentés.

Introduction

In general, barley has been used in the feeding of adult monogastrics and ruminants, all of which have an important digestible capacity. However, barley application is limited in monogastric nutrition, especially in the early ages.

The present situation of the cereal market and the agroclimatic conditions in Mediterrenean or Northern European countries will make necessary the application of barley in monogastric diets where barley utilization is low. However, barley has to compete against by-products (called substitute cereals) in the European Economic Community (Raymond, 1987).

Barley as an alternative cereal has been studied and used in poultry feeding in areas where it is an important crop, such as Scandinavian countries, Canada and some Western States in U.S.A. The initial studies on barley for poultry nutrition were conducted in the 1950's (Arscott *et al.*, 1957; Jensen *et al.*, 1957). However, since 1975, work has been conducted in research centers of Scandinavia, Australia and Canada. In Spain, the inclusion of barley in poultry diets has increased since the 1980's, and especially since the incorporation of Spain in the E.E.C. For this reason, the Dept. of Animal Nutrition of IRTA is working in the application of barley for feeding poultry and swine.

Barley in poultry feeding

Barley was used in laying hens but not in broilers, because this cereal has a low energy content. Currently, thanks to Scandinavian and Canadian research, this situation must be reconsidered. Nowadays, we can use the relationship between some analytical parameters of barley and the nutritive response in poultry. These parameters are related to genetic and environmental factors. For example, in France, Seroux and Metayer (1990) have found an approximation in M.E. values between 2 and 6 row barley. The main reason was the increase in production of one single variety. Along this line, our results confirm that some barley varieties have certain characteristics in terms of ß-glucan content, viscosity of the water extract and M.E. value, independently of climatic factors (Table 1) (Francesch *et al.*, 1989b). It would be very interesting to study the similarities between nutritional (expressed in A.M.E.) and brewing quality. Currently, the use of barley in poultry, especially in broilers, is possible thanks to enzymatic supplementation (Hesselman, 1989) and a better knowledge of the interaction between the cereal substrata and enzymes. The nature of the effect has already been reviewed by Chesson (1987). Other factors which allow the use of barley in broiler diets are pelleting and fractionation.

Barley in broiler diets

The utilization of barley in broiler diets reduces productivity (Campbell *et al.*, 1984), although the economic returns are in some cases improved (Table 2). However, the possibility of adding vegetable fats allows the inclusion of barley above 20% in broiler diets. An experiment was conducted with whole extruded soybean (24%) and replacement of corn by barley (74%) (Table 3), without changing productive efficiency. The results also show that enzyme supplementation improves food conversion rate.

Pelleting allows, in large measure, the use of barley in broiler diets. This procedure, according to Farrell *et al.* (1983) increases the M.E. of cereals. However, data from our department, show a higher response to pelleting in barley than in corn diets (Table 4).

Pelleting breaks cell walls and increases nutrient availability. However, there are possible negative effects of pelleting on enzyme application, due to the limited

Table 1. Proximal composition and Apparent Metabolizable Energy of some barleys. Crop 1987, 1988 (Francesch *et al.*, 1989b)[1].

Variety	Year	Density	C.P.	C.F.	Vis.	ß-glu.	A.M.E.
Dobla	87	64.3 ±3.7	12.4 ±1.1	4.50 ±0.5	4.48 ±0.6	3.01 ±1.27	3.254 ±40
	88	61.2 ±10.0	10.2 ±2.1	5.02 ±1.3	5.02 ±3.6	2.24 ±0.59	3.141 ±226
Kym	87	66.8 ±1.4	13.5 ±0.7	4.81 ±1.1	4.08 ±0.8	2.12 ±0.93	3.228 ±24
	88	56.6 ±13.1	12.9 ±1.0	5.34 ±1.6	5.14 ±2.6	2.77 ±0.43	3.039 ±269
Hassan	87	67.8 ±1.6	14.0 ±1.0	4.19 ±0.4	8.20 ±1.3	2.98 ±1.21	3.162 ±58
	88	60.8 ±11.2	14.5 ±1.6	4.83 ±0.9	9.38 ±1.8	3.83 ±0.08	3.068 ±131
Barbarrosa	87	61.9 ±6.9	11.3 ±2.5	5.54 ±0.8	4.76 ±1.2	3.39 ±0.82	3.131 ±155
	88	60.9 ±8.1	10.8 ±2.5	7.05 ±2.9	6.09 ±3.0	3.63 ±1.02	3.005 ±126
Alpha	87	64.4 ±5.5	13.4 ±3.1	5.18 ±0.3	4.23 ±1.3	2.39 ±0.92	3.165 ±21
	88	61.7 ±6.9	12.1 ±2.1	5.15 ±0.5	4.87 ±1.8	2.73 ±1.02	3.057 ±80

[1] Density (kg/hl); C.P. = Crude Protein (% dry matter); C.F. = Crude Fiber (% dry matter); Vis. = Viscosity of water extract (cSt); ß-glu. = whole ß-glucan (% dry matter); A.M.E. = Apparent Metabolizable Energy determined in adult cockerels (kcal/kg of dry matter)

Table 2. Utilization of barley in broiler diets (Campbell *et al.*, 1984).

Diet	42 days			To reach 1800 g live weight		
	Weight (g)	Feed intake (g)	F.C.R.[1]	Days	F.C.R.	Cost[2] %
Corn + wheat	1996	3484	1.75	39.1	1.71	100
Barley	1718	3530	2.05	43.2	2.08	90
Barley + enzyme	1891	3738	1.99	40.6	1.96	86

[1] F.C.R. = Food Conversion Rate
[2] Feeding cost relative to corn + wheat

Table 3. Utilization of barley and whole extruded soybean in broilers diets (IRTA-Dept. of Animal Nutrition, unpublished).

	Composition of the experimental diets			
	T-1[1]	T-2	T-3	T-3 + Enzyme
Corn (%)	60	39	16	16
Barley (%)	–	23	44	44
Extruded soybean (%)	–	12	24	24
	Productivity between 0-47 days[2]			
Weight (g)	1840 b	1878 a	1798 c	1832 b
Daily gain (g)	39.1 ac	39.7 a	38.0 b	38.8 bc
Daily feed intake (g)	85 a	86 a	83 b	83 b
Food Conversion Rate	2.195 a	2.184 a	2.194 a	2.138 b
% Abdominal fat	2.4 b	2.7 a	2.3 b	2.9 a

[1] T = Treatment
[2] Means followed by the same letter do not differ significantly at $p<0.05$ level

Table 4. Effect of pelleting process on Apparent Metabolizable Energy (A.M.E.) of corn or barley diets, with or without enzyme addition (Francesch *et al.*, 1989b).

Cereal	%	Diet	Enzyme	A.M.E. (kcal/kg)
Corn	55.7	Meal	–	3.313
		Pelleted	–	3.303
Barley	45.0	Meal	–	3.168
		Meal	+	3.372
		Pelleted	–	3.230
		Pelleted	+	3.238

thermostability of enzymes (Chesson, 1987). However, there is enough evidence which shows that the effect of pelleting in broiler diets with added fat (3%) does not exceed 80 °C (Campbell *et al.*, 1984). These results are confirmed by Brufau *et al.* (unpublished). The enzyme response has not been modified because it did not exceed the thermostability limits of the enzymes (Table 5).

Effects of enzymatic supplementation in broiler nutrition

Barley, oats and rye diets increase the viscosity of the digestive content and reduce the nutritive value of these

Table 5. Productivity of broilers fed with pelleted diets with high barley levels with commercial enzymes mixtures.

% barley	Age (days)	Enzyme	Weight (g)	Food Conversion Rate	
30/40	0-49	–	2381	2.118	(100)
		+	2371	2.040	(96.3)[1]
30/40	0-40	–	1839	2.030	(100)
		+	1902	1.960	(96.6)[1]
60	0-42	–	1836	2.168	(100)
		+	1869	2.025	(93.4)[2]
33	0-35	–	1470	1.790	(100)
		+	1475	1.730	(96.6)[3]

[1] IRTA - Dept. Animal Nutrition (unpublished)
[2] Wiedmer and Völker (1989)
[3] Elwinger and Säterby (1987)

cereals. The increment of viscosity prevents the action of digestive enzymes and reduces the absorption of nutrients. The viscosity of the water extract of barley differs between varieties. The enzymes degrade polysaccharides and reduce the viscosity of the water extract.

The efficacy of enzyme with ß-glucanasic activity is not related to the ß-glucan content of barley. The hydrolysis produced by enzyme mixtures of the polysaccharides in the cell wall is not enough to explain the response (White *et al.*, 1983). The enzymes degrade polysaccharides and reduce the viscosity of the water extract. According to Campbell *et al.* (1989) enzymatic efficacy is higher in barleys with high viscosity (Table 6). Our results do not agree with this view, since the same varieties with different viscosities have shown a similar response to enzyme supplementation (Table 7). Therefore, the level of enzymatic response must be related to the type of ß-glucan and stage of the grain maturation (Hesselman *et al.*, 1982; Hesselman and Aman, 1986; Fengler *et al.*, 1989) (Table 8).

Table 7. Effect of enzyme addition on Apparent Metabolizable Energy (A.M.E.) of barley 'Barbarrosa' of high or low viscosity (IRTA-Dept. Animal Nutrition, unpublished).

	Sta. Coloma[1]	Cervera[2]
Density (kg/hl)	67.5	63.0
Viscosity (cSt)	4.68	13.08
ß-glucans (%)	3.30	4.80
A.M.E. (kcal/kg)[3]		
without enzyme	3.150 (100)	3.074 (100)
with enzyme	3.430 (109)	3.336 (109)
A.M.E.n (kcal/kg)[4]		
without enzyme	3.022 (100)	2.972 (100)
with enzyme	3.315 (110)	3.210 (108)

[1] Wet and fresh area
[2] Dry area
[3] Apparent Metabolizable Energy
[4] Apparent Metabolizable Energy corrected by nitrogen retention

Table 6. Productivity of broilers fed with barley with high or low viscosity, with or without enzyme addition (Campbell *et al.*, 1989).

Relative viscosity[1]	Variety	%	Enzyme	21 days		
				Weight (g)	Food Conversion Rate	
Low (1.9 - 2.2)	Triumph	58	–	449 b[2]	1.56 b	(100)
			+	506 a	1.58 b	(101.3)
	Nirashi	58	–	435 b	1.63 b	(100)
			+	525 a	1.50 b	(92.0)
High (3.8 - 4.4)	Minerva	58	–	347 a	1.79 a	(100)
			+	542 b	1.53 b	(85.5)
	Yugoslavian	58	–	339 c	1.84 c	(100)
			+	519 a	1.55 b	(84.2)

[1] Relative viscosity (centipois) = viscosity of cereal water extract compared to water viscosity
[2] Means followed by the same letter do not differ significantly at p<0.05 level

Table 8. Effect of ß-glucanase application on broiler diets containing mature and immature barleys (Hesselman and Aman, 1986; Hesselman *et al.*, 1982).

Barley type	Enzyme	19 days		Intestine lenght (cm)	Viscosity (cSt)	% D.M.[2] of faeces 19 days
		Weight (g)	F.C.R.[1]			
Immature	–	381	2.03	1.25	28.0	19.0
	+	478	1.86	1.10		22.7
Mature	–	419	2.17	1.26	7.1	20.7
	+	535	1.90	1.16		23.3

[1] F.C.R. = Food Conversion Rate
[2] D.M. = Dry Matter

Table 9. Effect of enzyme application in diets with high barley content on water consumption and dry matter of faeces, and percentage of sticky droppings.

Barley (%)	Density	Viscosity (cSt)	Enzyme	Age[1] (days)	Water[2] consum. (g)	Dry matter faeces (%)	Age[3] (days)	% sticky droppings	Reference
45	67.8	3.4	–	28	239	23.1	9	58	IRTA - Dept. of Animal Nutrition (unpublished)
			+		213	22.0		39	
45	61.2	5.7	–	28	233	23.0	9	60	
			+		218	22.8		26	
45	58.1	8.4	–	16	156	25.5	16	50	Francesch *et al.* (1989a)
			+		137	29.5		11	
30	53.9		–	28	170	28.4	7	1.5[4]	IRTA - Dept. of Animal Nutrition (unpublished)
			+		148	30.2		1.2	
30	67.4		–	28	170	27.5		1.1	
			+		139	31.1		1.0	

[1] Water consumption was measured at this age
[2] Water consumption (g/animal/24 hours)
[3] Sticky droppings was performed at this age
[4] Score 1 to 3. 1 means lowest and 3 highest

In terms of productivity, these results represent an improvement in efficiency of feed utilization (Edney *et al.*, 1989). In addition, the incidence of sticky droppings during the first days of life, humidity in faeces, and water consumption decrease (Hesselman *et al.*, 1982; Elwinger and Saterby, 1987; Francesch *et al.*, 1989a) (Table 9).

We have observed that enzyme application increases the percentage of abdominal fat, probably because of better energy absorption. Skin pigmentation (Table 10) and carcass yield (Table 11) also improved. Ikegami *et al.* (1989) found a larger digestive tract when the viscosity of the diets increased. Similarly, Hesselman and Aman (1986) also observed a larger intestine in broilers fed with barley.

The objective of a mechanical treatment of grain is to obtain a fraction of barley with lower fiber content and homogenize the product. In Spain, barley is obtained with high fiber content and this type of treatment would be thus successful.

The fractionation procedure results in a fraction with higher starch content. At the same time, it increases the ß-glucan content, so that there is more negative effect of viscosity from ß-glucans and their utilization of the diets. For this reason, there is a response to enzymes

Table 10. Effect of enzyme application on abdominal fat content and leg pigmentation of broilers.

Barley variety	% inclusion	Enzyme	% abdominal fat	Leg pigmentation[1]	Reference
Barbarrosa	45	–	1.9		IRTA (unpublished)
		+	2.2		
Beka	45	–	2.1		
		+	2.3		
Albacete	45	–	2.0		
		+	2.3		
Barbarrosa	40	–		5.9	Brufau (1989)
		+		8.4	

[1] Roche scale

Table 11. Efficacy of enzyme application on carcass yield in broilers (0-40 days) (IRTA - Dept. of Animal Nutrition, unpublished)[1].

	T-1[2]	T-1[3]	T-2[2]	T-2[3]
Carcass yield (%)	74.8	75.1	74.5	75.2
Viscerae (%)	10.9	10.3	10.9	10.7
Intestine (%)	5.7	5.3	5.9	5.4
Food Conversion Rate	2.011	1.971	2.076	2.000

[1] T = Treatment; T-1 = 15-20 % of barley; T-2 = 30-40 % barley
[2] No enzyme addition. Pelleted feed
[3] Addition of 1 g ß-glucanase/kg of feed

supplementation in fractioned grain (Table 12). A similar effect was produced with hull-less barley added to enzymes (Newman and Newman, 1987).

Barley in laying hen feeding

The use of barley in laying hen diets has no effects on productivity results. According to Coon *et al.* (1987) (Table 13), corn could be replaced by barley without reducing egg production. However, high levels of barley require the inclusion of fat in considerable amounts to

Table 12. Effect of enzyme addition in diets with low fiber fraction of barley, whole barley and hull-less barley content.

Barley type	%	C.F.[1] (%)	Vis.[2] (cSt)	Enzyme	Weight (g)	F.C.R.[3]
Whole barley A[4]	45	4.8	3.4	–	1974	2.080
				+	1987	1.995
Low fiber fr. A[4]	45	2.7	4.3	–	1987	2.094
				+	2073	1.994
Whole barley B[4]	45	6.1	5.7	–	1982	2.058
				+	2003	1.965
Low fiber fr. B[4]	45	3.2	7.8	–	2013	2.023
				+	1983	1.956
Hull-less barley[5]	56	2.0	3.2	–	608	1.68
				+	660	1.51

[1] C.F. = Crude Fiber
[2] Vis. = Viscosity
[3] F.C.R. = Food Conversion Rate
[4] IRTA - Dept. Animal Nutrition (unpublished)
[5] Newman and Newman (1987)

increase the energy level of the diet. The quality of the added fat and the adjustement of the level of linoleic acid, which is a nutrient necessary to improve egg size, has to be considered carefully (Table 14 and 15).

Enzyme application in laying hen diets is less efficient than in broilers (Al Bustany and Elwinger, 1988). However, according to Nasi (1988) enzyme supplementation produces an improvement in the initial and the final period of production. In our experiments we have observed lower intake and better commercial classification at the beginning of laying (Fig. 1). This improvement in the initial period may be due to an incomplete development of the gut in this period; this effect is similar to that found in broilers. Gohl *et al.* (1978) and Herstad (1987) found that inclusion of a high barley level increases the humidity of faeces and the percentage of dirty eggs. Enzyme application could avoid this problem. The internal egg quality (expressed by Haugh units) is also improved in barley diets (Table 16).

Barley in swine feeding

Barley is a basic cereal for swine feeding in the growing, finishing and breeding periods. Barley has a lower energetic value than cereals with less percentage of fiber, as corn and wheat. However, in Europe, in swine feeding, barley is the best cereal because it produces better carcasses in terms of market demands.

There are some very accurate prediction equations to determine the energy content of barley (INRA, 1984; Perez *et al.*, 1980). In these equations every 1% of crude fiber reduce energy value by 3%:

E:D = 4072 - 110 * % C.F. (R = 0.88 and ster = 0.49) (Fig. 2).

In swine, processing the cereal is very important. According to Lawrence (1985) the diameter of hammer mill must be 2 mm and rolling has the greatest effect on digestibility. Whole barley presentation is less digestible and therefore less efficient than ground barley (Table 17).

Pelleting of diets with a high level of barley improves performance with respect to mash diets. Moreover, according to Lawrence (1985) there are some differences in the digestive coefficients of energy in diets with 65% of barley depending on the pelleting. These coefficients are higher in cold pelleting (Table 18).

In swine feeding, the mechanic fractionation of the grain and separation of a fraction with lower fiber content (Table 19) is very interesting. The reduction of fiber content increases digestibility (Graham, 1988). Milling the grain increases the surfaces of attack of digestive enzymes (Lawrence, 1973; Fernandez *et al.*, 1975). This process improves the average daily gain by 12% and the feed/gain by 7%. Also, it increases energy

Table 13. Substitution of corn by barley in diets for laying hens (Coon *et al.*, 1987).

	Percentage of corn substituted by barley			
	0	17	50	100
Corn (%)	66	53	30	0
Barley (%)	0	10	30	57
Additional fat (%)	0.5	2.5	5.4	9.7
% Lay	84	84	83	81
Feed intake (g)	106	117	118	113
Food Conversion Rate	2.36	2.61	2.74	2.62
Egg weight (g)	54.9	54.6	54.6	54.8

Table 14. Influence of fat quality on barley diets for laying hens (Brufau *et al.*, 1985).

	Animal fat (18:2 9%)		Fat mixture (18:2 30%)	
% Fat	6	1	6	1
% Barley	65	70	65	70
% Lay	86	83	85	83
Food Conversion Rate	2.30	2.45	2.37	2.43
Egg weight (g)	58.2	57.3	59.2	58.2
% eggs > 60 g	43.2	35.6	56.8	45.0

Table 15. Utilization of barley and whole extruded soybean in laying hen diets (IRTA-Dept. Animal Nutrition, unpublished).

	Treatments			
	T-1	T-2	T-3	T-4
Composition of diets (%)				
Corn	38	25	7	18
Barley	27	40	57	48
Whole extruded soybean	0	6	14	19
Fat	3	3	3	–
From 22 to 64 weeks				
Number of eggs	4757	4581	4556	4728
Feed intake (g)	104a	103ab	101b	103ab
Food Conversion Rate	2.219	2.270	2.196	2.214
Egg weight (g)	58.4	58.2	58.0	58.3
Gain (g)	253	203	198	170
Egg quality				
Haugh units (46 weeks)	77.3	78.9	81.6	79.7
% (18:0)	11.5	12.3	13.7	15.0
% (18:1)	31.0	34.6	31.3	27.1
% (18:2)	11.0	14.2	16.3	20.1
% (20:4)	2.7	2.7	3.1	3.4

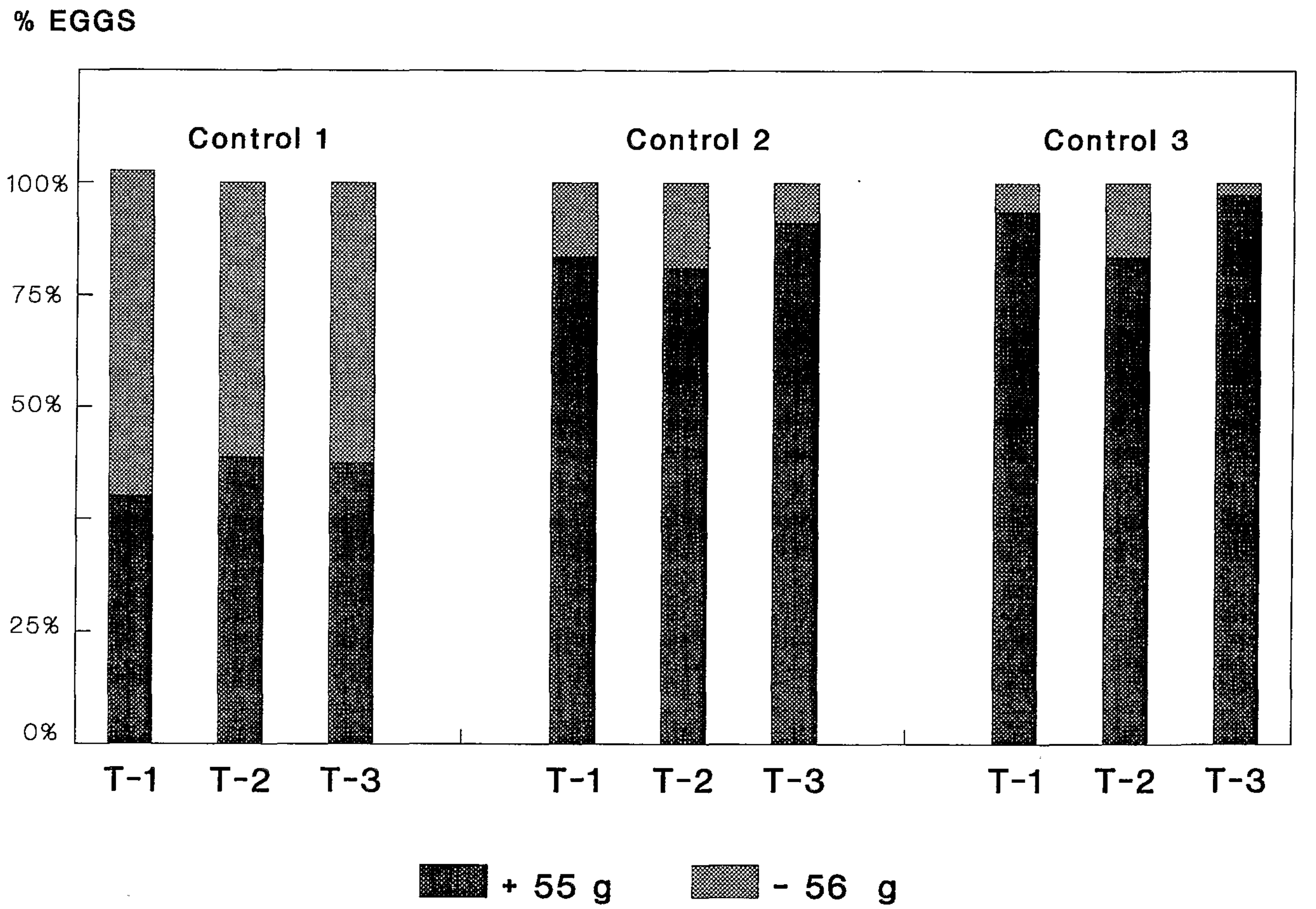

Fig. 1. Effect of enzyme addition at different levels on percentage of eggs >or= 55 g. T-1 = 0 ppm. enzyme; T-2 = 100 ppm. enzyme; T-3 = 200 ppm. enzyme (IRTA - Dept. Animal Nutrition, unpublished).

Table 16. Influence of cereal level on egg Haugh units[1].

EXPERIMENT 1 (Brufau and Francesch, 1983)						
Corn (%)	64	19	17			
Barley (%)	–	49	45			
Fat (%)	0.5	2	4			
Haugh Units	78.7	81.6	80.8			
EXPERIMENT 2 (Brufau *et al.*, 1985)						
Barley (%)	65	65	65	68	70	70
Animal fat (%)	6	–	3	–	1	–
Vegetal fat (%)	–	6	–	3	–	1
Haugh Units	84.0b	83.9b	86.7a	84.3b	84.4b	85.1ab
EXPERIMENT 3 (Patersson *et al.*, 1988)						
Mashed wheat (%)	89	43	20	0		
Corn (%)	–	36	55	67		
Haugh Units	93.6a	89.8b	90.2b	87.7c		

[1] Means followed by the same letter do not differ significantly at p<0.05 level

Table 17. Influence of diameter of hammer screen on barley digestibility and productivity in swine (Lawrence, 1985).

	Grinding			Crimping 4.1 mm	Rolling 3.3 mm	Whole
	1.4 mm	2.1 mm	2.5 mm			
Apparent Digestibility (%)						
Dry matter	80.5	79.8	78.2	79.2	80.9	63.6
Gross energy	80.3	79.8	78.0	80.9	79.6	63.8
Productivity[1]						
D.A.F.I. (g)	660	665	640	590	660	510
F.C.R.	3.14	3.17	3.19	3.40	3.10	3.98

[1] D.A.F.I. = Daily Average Feed Intake; F.C.R. = Food Conversion Rate

consumption and the efficiency of the energy consumed. The fractionation of barley would reduce the fiber content and would homogenize the product obtained from a variety of sources. The results could be similar to those of Thacker *et al.* (1988a) with hull-less barleys. Also it could improve carcass yield (Truscott *et al.*, 1988).

Enzyme application in swine feeding has been studied by many authors. According to Graham *et al.* (1986, 1988, 1989) enzyme application of barley diets in swine increases the ileal digestibility of both starch dry matter and ß-glucan (Table 20).

According to Thacker *et al.* (1988b, 1989) dry matter digestibility increased. However, they did not obtain a positive response on growth and feed conversion. According to Inborr and Ogle (1988) there is an improvement of feed conversion in piglets with application of ß-glucanases and amylases. This is caused, mainly, by a reduction of feed consumption. This may be caused by higher availability of sugars which would reduce appetite (Table 21).

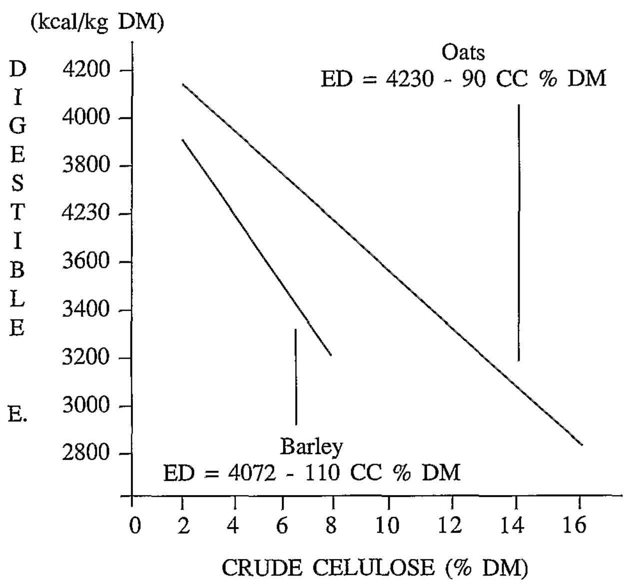

Fig. 2. Influence of crude fiber content on the energy value of barley (Perez and Leuillet, 1986).

In our department, we have applied ß-glucanases 1 g/kg to a barley diet or to the low fiber fraction of the same barley. We have observed a negative interaction between enzyme application and the low fiber fraction (Table 22). According to Inborr *et al.* (1988) a similar effect is observed when enzymes are used with cooked barley.

In summary, the efficiency of enzyme application in swine is not as clear as in broilers. Probably, this is because ß-glucans have less negative effects. The negative results with enzymatic application may be caused by poor knowledge of the correct dose. It is possible that at low doses enzymes increase the viscosity of the gut contents.

Table 18. Effects of differing pelleting processes on a diet for swine containing 65% barley and 20% wheatings (Lawrence, 1985).

	Meal	Cold pelleting	Steam pelleting
Apparent Digestibility Coefficients (%)			
Dry matter	76.8	79.8	77.6
Energy	76.5	79.9	77.9
Digestible energy content (kcal/kg)	2.960	3.170	3.100

Table 19. Productivity of weaning pigs (10 to 23 kg live weight) fed low fiber fraction barley of pigs (IRTA - Dept. of Animal Nutrition, unpublished)[1].

	Experiment 1		Experiment 2	
	T-1	T-2	T-1	T-2
Barley (%)	50	–	50	–
Fractionated barley (%)	–	50	–	50
Wheat (%)	12	12	14	15
M.E. (kcal/kg)	3045	3167	3017	3100
A.D.G. (g)	470	534	516	580
A.D.F.I. (g)	985	1018	1005	1048
D.E.F.I. (cal)	2999	3244	3032	3248
F.C.R.	2.097	1.912	1.945	1.805
F.C.R. (cal/g)	6.38	6.03	5.87	5.60

[1] T = Treatment; M.E. = Estimate Metabolizable Energy, 096 (4072 - 110 C.B. %); A.D.G. = Average Daily Gain; A.D.F.I. = Average Daily Feed Intake; D.E.F.I. = Daily Energy Feed Intake; F.C.R. = Food Conversion Rate

Table 20. Effect of enzyme addition in barley diets on ileal and fecal apparent digestibility of main dietary components (Graham *et al.*, 1989)[1].

Treatment	Energy	Starch	Dietary fiber	Arabinoxylans	ß-glucan
Ileal Apparent Digestibility (%)					
Control	60.3	90.3	57.0	43.1	95.6
Pelleted	63.3	94.9	55.3	40.9	95.8
Enzyme suppl.	61.9	92.7	58.1	46.4	97.2
Pelleted + enzyme suppl.	63.9	95.8	61.3	49.0	96.9
Fecal Apparent Digestibility (%)					
Control	77.8	98.3	71.8	66.2	100
Pelleted	78.7	99.7	69.4	62.6	100
Enzyme suppl.	78.9	99.0	72.8	67.2	100
Pelleted + enzyme suppl.	80.8	99.7	72.6	68.1	100

[1] Enzyme added = 5 g/kg of feed

Conclusion

Barley utilization in poultry can increase substantially, especially through the use of new varieties. Also, because of application of enzyme with ß-glucanasic activity.

In swine feeding, the possibility of increased utilization is not as important, but using a new mechanical process we can obtain a low fiber fraction of barley with a higher nutritive value. These aspects and application of enzymes could allow the utilization of this cereal in pigs in earlier stages of growth.

Table 21. Effect of enzyme addition to diets for weaning pigs (Inborr and Ogle, 1988)[1].

	Treatments			
	T-1	T-2	T-3	T-5
Enzymes A.B.G	–	+	–	+
Enzymes A.C.P.	–	–	+	+
Final live weight (kg)	14.4	15.1	13.2	13.7
A.D.G. (g)	211	234	191	203
Feed intake[2] (kg) (total/animal)	13.8a	12.7ab	10.2c	11.3bc
F.C.R.	1.30	1.13	1.09	1.15

[1] A.B.G. = α-amylase + ß-glucanase + Glucoamylase; A.C.P. = amylolytic + celulolytic + proteolytic enzymes; A.D.G. = Average Daily Gain; F.C.R. = Food Conversion Rate
[2] Means followed by the same letter do not differ significantly at $p<0.05$ level.

Table 22. Effect of enzyme application in diets with whole and low fiber fraction of barley (10 - 23 kg of live weight) (IRTA - Dept. Animal Nutrition, *unpublished*)[1].

	%	A.D.G. (g)	A.D.F.I. (g)	F.C.R.
Whole barley	50	517	1005	1.945
Whole b. + enzyme	50	510	1003	1.970
Low fiber fraction	50	578	1049	1.813
Low fiber fraction + enzyme	50	463	1002	2.175

[1]A.D.G. = Average Daily Gain; A.D.F.I. = Average Daily Feed Intake; F.C.R. = Food Conversion Rate

References

AL BUSTANY, Z. and ELWINGER, K. (1988): Whole grain, unprocessed rape seed and ß-glucanase in diets for laying hens. Swedish J. Agric. Res. *18*:31.

ARSCOTT, C.H., HULIT, B. and PAUTZ, R.H. (1957): The use of barley in high efficiency broilers rations. 3. Effects of pellets and raground pellets and growth and efficiency of feed utilization. Poult. Sci. *36*:1388-1389.

BRUFAU, J. (1989): Aspects of egg yolk pigmentation. *In* la Conferenza Internazionale di Produzione di Alimenti per Animali, Piacenza, Italy (in press).

BRUFAU, J. and FRANCESCH, M. (1983): Capacidad de sustitución de maíz por diversas variedades de cebada en ponedoras. Pages 215-226 *in* Memorias del XXI Symposium Científico WPSA, Barcelona, Spain. Spanish Branch of World's Poultry Science Association.

BRUFAU, J., FRANCESCH, M. and GONZALEZ, R. (1985): Efectos de la sustitución total de maíz por cebada en dietas de ponedoras. Pages 199-215 *in* Memorias del XXIII Symposium Científico WPSA, Barcelona, Spain. Spanish Branch of World's Poultry Science Association.

CAMPBELL, G.L., CLASSEN, H.L. and SALMON, R.E. (1984): Enzyme supplementation of barley diets for broilers. Feedstuffs May 1984:26-27.

CAMPBELL, G.L., ROSSNAGEL, B.G., CLASSEN, H.L. and THACKER, P.A. (1989): Genotypic and environmental differences in extract viscosity of barley and their relationship to its nutritive value for broiler chickens. Anim. Feed Sci. Technol. *26*:221-230.

CHESSON, A. (1987): Supplementary enzymes to improve the utilization of pig and poultry diets. Pages 71-89 *in* Recent Advances in Animal Nutrition (Haresign, W. and Cole, D.J.A., eds.). Butterworths, London, UK.

COON, C.N., OBI, I. and HAMRE, M.L. (1987): Use of barley in laying hen diets. Poult. Sci. *67*:1306-1313.

EDNEY, M.J., CAMPBELL, G.L. and CLASSEN, H.L. (1989): The effect of ß-glucanase supplementation on nutrient digestibility and growth in broilers given diets containing barley, oat groats or wheat. Anim. Feed Sci. Technol. *25*:193-200.

ELWINGER, K. and SATERBY, B. (1987): The use of ß-glucanase in practical broiler diets containing barley or oats. Swedish J. Agric. Res. *17*:133-140.

FARRELL, S., THOMPSON, E., and CHOICE, A. (1983): Effects of milling and pelleting of maize, barley and wheat on their metabolizable energy value for cockerels and chicks. Anim. Feed Sci. Technol. *9*:99-105.

FENGLER, A.I., AHERNE, F.X. and ROBBLEE, A.R. (1989): Influence of germination of cereals on viscosity of their extracts and nutritive value. Anim. Feed Sci. Technol. *28*:243-253.

FERNANDEZ, T.H., HUTTON, K. and SMITH, W.C. (1975): A note on the use of micronized barley for growing pigs. Anim. Prod. *20*:307-310.

FRANCESCH, M., PEREZ-VENDRELL, A., ALMIRALL, M., ROURA, E. and BRUFAU, J. (1989a): ß-glucanase supplementation in barley based diets for broiler. Effects of dry matter content of excreta, water consumption, sticky droppings and carcass yield. Pages 309-313 *in* Proceedings of the 7th European Symposium on Poultry Nutrition, LLoret de Mar, Spain. Institut de Recerca i Tecnologia Agroalimentàries, Barcelona, Spain.

FRANCESCH, M., PEREZ-VENDRELL, A. and BRUFAU, J. (1989b): Valoración nutritiva de cebadas en la alimentación de broilers. Mejora de su utilización. Pages 135-146 *in* XXVIII Symposium de la Sección española de la WPSA, Expoaviga, Barcelona. Fira de Barcelona, Spain.

GOHL, B., ALDEN, S., ELWINGER, K. and THOMKE, S. (1978): Influence of ß-glucanase on feeding value of barley for poultry and moisture content of excreta. Br. Poult. Sci. *19*:41-47.

GRAHAM, H. (1988): Dietary fiber concentration and assimilation in swine. Pages 76-80 *in* ISI Atlas of Science - Animal and Plant Sciences.

GRAHAM, H., FADEL, J.G., NEWMAN, C.W. and NEWMAN, R.K. (1989): Effect of pelleting and ß-glucanase supplementation on the ileal and fecal digestibility of a barely-based diet in the pig. J. Anim. Sci. *67*:1293-1298.

GRAHAM, H., HESSELMAN, K., JONSSON, E, and AMAN, P. (1986): Influence of ß-glucanase supplementation on digestion of a barley-based diet in the pig gastrointestinal tract. Nutr. Rep. Int. *34*(6):1089-1096.

GRAHAM, H., LOWGREN, W., PETTERSSON, D. and AMAN, P. (1988): Effects of enzyme supplementation on digestion of a barley/ pollard-based pig diet. Nutr. Rep. Int. *38*(5):1073-1079.

HERSTAD, O. (1987): Cereal with higher fibre content (barley, oats, millet). Pages 5-13 *in* Proceedings of the 6th European Symposium on Poultry Nutrition, Konigslutter, Germany. German Branch of World's Poultry Science Association.

HESSELMAN, K. (1989): The use of enzymes in poultry diets. Pages 31-45 *in* Proceedings of the 7th European Symposium on Poultry Nutrition, Lloret de Mar, Spain. Institut de Recerca i Tecnologia Agroalimentàries, Barcelona, Spain.

HESSELMAN, K. and AMAN, P. (1986): The effect of ß-glucanase on the utilization of starch by broiler chickens fed low and high viscous barley. Anim. Feed Sci. Technol. *15*:83-93.

HESSELMAN, K., ELWINGER, K. and THOMKE, S. (1982): Influence of increasing levels of ß-glucanase on the productive value of barley diets for broiler chickens. Anim. Feed Sci. and Technol. *7*:351-358.

IKEGAMI, S., TSUCHIHASHI, F., NARADA, H., TSUCHIHASHI, N., NISHIDE, E. and INNAMI, S. (1989): Effect of viscous indigestible polysaccharides on pancreatic-biliary secretion and digestive organs in rats. J. Nutr. *120*:353-360.

INBORR, J., NASI, M., and SUOMI, K. (1988): The effect of enzyme treatment of cooked barley and supplementation of piglet diets on the digestibility of barley and piglet performance. J. Agric. Sci. in Finland *60*:685-699.

INBORR, J. and OGLE, R.B. (1988): Effect of enzyme treatment of piglet feeds on performance and post weaning diarrhoea. Swedish J. Agric. Res. *18*:129-133.

INRA (1984): L'alimentation des animaux monogastriques. Porc, lapin, volailles. INRA, Paris, France, 282 pp.

JENSEN, L.S., FRY, R.E., ALLRED, J.B. and McGINNIS, J. (1957): Improvement in the nutritional value of barley for chicks by enzyme supplementation. Poult. Sci. *36*:919-921.

LAWRENCE, T.L.J. (1973): An evaluation of micronization process for preparing cereals for growing pig. 1. Effects on digestibility and nitrogen retention. Anim. Prod. *16*:99-107.

LAWRENCE, T.L.J. (1985): Processing and preparation of cereals for pigs diets. Pages 230-245 *in* Recent Developments in Pig Nutrition (Cole, D.J.A. and Haresign, W., eds.). Butterworths, London, UK.

NASI, M. (1988): Enzyme supplementation of laying hen diets based on barley and oats. Pages 199-204 *in* Biotechnology in the feed industry. Proceedings of Alltech's 4th Annual Symposium, Kentucky, USA.

NEWMAN, R.K. and NEWMAN, C.W. (1987): ß-glucanase effect on the performance of broiler chicks fed covered and hull-less barley isotypes having normal and waxy starch. Nutr. Rep. Int. *36*:693-699.

PATTERSON, P.H., SUNDE, M.L., SCHIEBER, E.M. and WHITE, W.B. (1988): Wheat Middlings as an alternate feedstuff for laying hens. Poult. Sci. *67*:1329-1337.

PEREZ, J.M. and LEUILLET, M. (1986): Les céréales dans l'alimentation du porc: composition et valeur nutritive. Perspectives Agricoles *106*:56-66.

PEREZ, J.M., RAMOELINTSALAMA, B. and BOURDON, D. (1980): Prevision de la valeur energetique de l'orge pour le porc a partir des teneurs en constituants membranaires. Journés de la Recherche porcine en France *12*:273-285.

RAYMOND, W.F. (1987): Increasing the use of cereals in livestock feeding. Report EUR 11146. Commission of the European Communities.

SEROUX, M. and METAYER, J.P. (1990): Qualité nutritionelle des cereales a paille et du sorgho etude des facteurs de variation. Pages 17-24 *in* Proc. Symposium qualité des céréales, des oleagineux et des protéagineux français pour l'alimentation animale. Institut Technique des Céréales et des Fourrages, Paris, France.

THACKER, P.A., BELL, J.M., CLASSEN, H.L., CAMPBELL, G.L. and ROSSNAGEL, B.G. (1988a): The nutritive value of hull-less barley for swine. Anim. Feed Sci. Technol. *19*:191-196.

THACKER, P.A., CAMPBELL, G.L. and GROOTWASSINK, J.W.D. (1988b): The effect of beta-glucanase supplementation on the performance of pigs fed hull-less barley. Nutr. Rep. Int. *38*(1):91-99.

THACKER, P.A., CAMPBELL, G.L. and GROOTWASSINK, J.W.D. (1989): The effect of sodium bentonite on the performance of pigs fed barley-based diets supplemented with beta-glucanase. Nutr. Rep. Int. *40*(3):613-620.

TRUSCOTT, D.R., NEWMAN, C.W. and ROTH, N.J. (1988): Effects of hull and awn type on the feed value of betzes barley III. Growth performance, carcass characteristics and nitrogen and energy digestibility by pigs. Nutr. Rep. Int. *38*(2):221-230.

WHITE, W.B., BIRD, H.R., SUNDE, M.L. and MARLETT, J.A. (1983): Viscosity of ß-glucan as a factor in the enzymatic improvement of barley for chicks. Poult. Sci. *62*:853-862.

WIEDMER, H. and VÖLKER, L. (1989): Enzyme supplementation of a barley-based diet fed to broiler chickens under practical conditions. Page 322 *in* Proceedings of the 7th European Symposium on Poultry Nutrition, Lloret de Mar, Spain. Institut de Recerca i Tecnologia Agroalimentàries, Barcelona, Spain.