

## Potential use of *triticale* in diets for rainbow trout: effects of dietary levels and incidence of cooking

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**Summary** — It is recognized that an increase in digestible energy (DE) can improve the growth performance and protein retention efficiency in rainbow trout. Growth and digestibility trials were conducted to evaluate possible incorporation of *triticale* (Clercal, a soft wheat x rye hybrid, hexaploid variety) as a potential source of DE for rainbow trout. Four diets were formulated with graded levels of native *triticale* (0–30% of dry matter) and 2 others with pre-cooked *triticale* at 20 and 30% of DM. All diets were isoproteic (crude protein: 43% DM) and isoenergetic (gross energy: 20 kJ/g DM). Digestibility of dry matter, starch and energy was affected by both level and nature of *triticale*. Cooking (15 min, 110 °C) improved nutrient digestibilities of diets containing *triticale*. Growth performance and nutrient retention efficiencies were higher in fish fed diets containing precooked *triticale* than in those receiving equivalent amounts of native *triticale*. *Triticale* appears to hold potential value as an ingredient in trout diets provided some pretreatment of the cereal is made to improve starch digestibility.

***triticale* / rainbow trout / digestibility / starch / energy**

**Résumé** — Possibilité d'incorporation du *triticale* dans le régime alimentaire de la truite arc-en-ciel. Il est bien établi qu'une augmentation de l'apport en énergie digestible (sous forme de lipides ou de glucides digestibles) permet d'améliorer les performances zootechniques chez la truite arc-en-ciel. Nous avons réalisé des essais afin d'évaluer la possibilité d'incorporation du *triticale* (variété hexaploïde, Clercal, hybride blé tendre x seigle) en tant que source d'énergie digestible dans les aliments destinés à la truite arc-en-ciel. Six aliments expérimentaux ont été formulés ayant des taux variables de *triticale* cru (0, 10, 20 et 30% de la matière sèche de la ration) ou du *triticale* précuit (20 et 30% MS). Des essais zootechniques ont été réalisés à une température de 15 à 17 °C sur une durée de 8 semaines. Des mesures des coefficients d'utilisation digestive apparente (CUDa) ont également été effectuées. Nos résultats montrent que l'incorporation du *triticale* non-traité diminue les CUDa de la matière sèche, de l'amidon et de l'énergie. La cuisson (110 °C, 5 min) permet d'améliorer de façon significative les valeurs des CUDa. Cette amélioration se traduit également par un meilleur indice de consommation et par une augmentation des coefficients d'utilisation protéique et énergétique chez les truites recevant des régimes contenant du *triticale* précuit. En conclusion, il apparaît que le *triticale* précuit peut être incorporé jusqu'à un taux de 30% de la ration destinée aux truites.

***triticale* / digestibilité / truite arc-en-ciel / énergie / glucides**

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## INTRODUCTION

Commercial diets for domestic animals usually contain a high level of cereals, which represent the major and most economic source of energy available on the market. However, diets for carnivorous fish, such as salmonids, contain high levels of proteins mainly in the form of fish meal, an expensive and increasingly scarce raw material. Several works have been carried out over the past decade to evaluate the effects of incorporation of carbohydrates in the diets of salmonids (Bergot, 1979; Pieper and Pfeffer, 1979; Hilton and Atkinson, 1982; Spannhof and Plantikow, 1983; Kaushik and Oliva Teles, 1985; Hilton *et al*, 1987; Kaushik *et al*, 1989).

Carbohydrates represent the major and common source of energy in diets of higher animals usually provided by the starch content of cereals which enable optimization of formulating costs (Hilton *et al*, 1987). However, some controversy persists as regards the optimum level of inclusion of carbohydrates. Bergot and Breque (1983) and more recently Kaushik and Oliva Teles (1985) and Kaushik *et al* (1989) reported that technological, hydrothermic treatment of crude starch would increase energy availability and the efficiency of protein utilization by salmonids.

*Triticale*, a wheat x rye hybrid, is harvested in many regions of the world (Hadjipanayiotou *et al*, 1985) in order to associate the productive capacity of wheat with the resistance of rye. Despite the high production potential together with its lower cost, the use of *triticale* for human consumption is still confronted by consumer reluctance. Nonetheless, *triticale* has been successfully incorporated in feeds for broilers and pigs, being considered 1 of the cheapest carbohydrate sources and a good substitute for corn and wheat middlings in animal diets without any adverse

effects on growth and feed efficiency (Bragg and Sharby, 1970; Fernandez and MacGinnis, 1974; Gerry, 1975; Bixler *et al*, 1986).

The main purpose of this work was to evaluate the effects of incorporation of *triticale* in rainbow trout diets and also to determine the optimum dietary inclusion levels.

## MATERIAL AND METHODS

### Diets

Six experimental diets were formulated to incorporate different levels of crude or precooked *triticale* (Clercal, hexaploid variety, a soft-wheat x rye hybrid, number of chromosomes = 42). Three diets contained crude *triticale* at 10, 20 and 30% of dry matter (diets T<sub>10</sub>, T<sub>20</sub> and T<sub>30</sub>, respectively) and 2 other experimental diets contained precooked *triticale* (15 min at 110 °C in an autoclave) at 20 and 30% levels (diets CT<sub>20</sub> and CT<sub>30</sub>, respectively). A control diet (T) was also formulated, based on fish meal as the only protein source and at an isoproteic (crude protein: 43% DM) and isoenergetic (gross energy: 20 kJ/g DM) level common to all diets. The above 6 diets were tested in duplicate. In order to examine experimental conditions, 1 batch of fish was fed a commercial diet (diet C). The composition of the diets is reported in table I. The amino acid composition of the experimental diets is provided in table II.

### Growth studies

325 under-yearling rainbow trout (*Salmo gairdnerii*), with a mean body weight of 102 ± 2 g, obtained from the Portuguese Aquaculture Services, were randomly divided into 13 equal groups and placed into fiberglass tanks of 400 l capacity receiving a water flow rate of 20 l/min. The trials were conducted at the experimental farm station of Trás-os-Montes University, Portugal.

The water was saturated with dissolved oxygen and the temperature ranged between 15–

**Table 1.** Formulation and chemical composition of the diets. <sup>1</sup> NRC, 1981; <sup>2</sup> calcium lignosulphite; \* precooked *triticale* (110 °C-15 min); nd = not determined.

Ingredients (% DM)	Control	Diets					Commercial
		T <sub>10</sub>	T <sub>20</sub>	T <sub>30</sub>	CT <sub>20</sub>	CT <sub>30</sub>	
Fish meal	62	60	59	58	59	58	
Dextrin	30	22	13	4	13	4	
<i>Triticale</i>	—	10	20	30	20*	30*	
Cod liver oil	6	6	6	6	6	6	
Min vit premix <sup>1</sup>	1	1	1	1	1	1	
Binder <sup>2</sup>	1	1	1	1	1	1	
<i>Chemical composition</i>	<i>Control</i>	<i>T<sub>10</sub></i>	<i>T<sub>20</sub></i>	<i>T<sub>30</sub></i>	<i>CT<sub>20</sub></i>	<i>CT<sub>30</sub></i>	
Dry matter (DM)	92.2	93.2	93.0	92.3	93.8	94.9	88.9
Protein (N x 6.25) (% DM)	42.7	42.6	42.4	42.8	42.6	42.9	42.6
Fat (% DM)	10.1	11.1	11.1	11.8	11.9	11.9	10.2
Starch (% DM)	14.4	15.0	16.3	17.2	17.4	17.9	nd
Gross energy (kJ/g DM)	20.6	20.5	20.6	20.6	20.7	21.1	20.1
Ash (% DM)	12.2	12.1	12.8	12.2	12.4	12.4	13.8

17 °C during the trial. After a week's adaptation period, fish were fed the experimental diets for 8 wks, twice a d, morning and afternoon (10 am and 5 pm). Diets were distributed at a rate of 2% of body weight per day. All fish were weighed every 2 wks and the feed intake levels were adjusted at such weighings. Final body weights of all fish were also recorded at the end of the 8 wk growth trial. Ten fish were removed from an initial group and from each tank at the end of the trial and the chemical composition of eviscerated and non-eviscerated animals was determined.

### Digestibility

Apparent digestibility coefficients (ADC) were determined using the indirect method with diets containing 1% of Cr<sub>2</sub>O<sub>3</sub>. Twenty fishes per tank (4 tanks per treatment) were adapted to the respective experimental diets and tanks and the faecal samples were collected using the apparatus developed by INRA (Choubert *et al*, 1982:

cylindrical tanks of 60 l capacity with a flow rate of 5 l/min). For each diet, faecal samples were collected from the 4 groups of fish over 7 d and frozen daily. After freeze-drying, the faeces were analyzed for chromic oxide, protein, starch and energy contents.

### Blood metabolites

After the growth trial, 6 groups of 25 fishes were fed the experimental diets in the usual manner for 4 d. Another group were fasted for 4 d. On the 5th d, a single meal was offered at 9 am and individual blood samples were collected with heparinized syringes from the caudal vessel of 3 anesthetized (ethylene glyco monophenyl ether 1:2500) fishes from each group, including fasted fish at different intervals after the meal (0, 3, 6, 9, 12 and 24 h). The blood samples were then centrifuged (3000 rpm, 20 min) for separation of plasma and stored frozen before analysis of glucose and total free amino acid concentrations.

**Table II.** Amino acid composition of experimental diets (g/16 g N) along with the EAA requirement values for salmonids (NRC, 1981). \* In the absence of cystine; \*\* Phenylalanine + tyrosine.

	Diets						EAA Needs
	T	T <sub>10</sub>	T <sub>20</sub>	T <sub>30</sub>	CT <sub>20</sub>	CT <sub>30</sub>	
Asp	9.53	9.38	9.20	8.86	9.19	9.20	
Thr	4.17	4.24	4.21	4.07	4.21	4.53	
Ser	3.97	4.01	4.16	3.93	4.06	3.90	
Glu	13.43	13.97	13.98	14.91	14.65	15.07	
Pro	4.20	4.71	4.08	5.06	4.92	5.17	
Gly	6.68	6.24	6.46	6.16	6.41	6.06	
Ala	6.07	6.02	5.96	5.80	5.91	5.96	
Cys	0.71	0.63	0.52	0.74	0.75	0.55	
Val	5.26	5.32	5.15	5.25	5.31	5.38	3.20
Met	2.68	2.86	2.67	2.70	2.71	2.82	4.00*
Ile	4.35	4.46	4.21	4.35	4.39	4.56	2.20
Leu	7.31	7.50	7.24	7.26	7.34	7.48	3.90
Tyr	3.24	3.33	3.22	3.00	3.43	3.37	
Phe	4.05	4.09	4.00	3.93	4.12	4.19	5.10**
His	2.50	2.48	4.31	2.45	2.54	2.64	1.80
Lys	7.56	7.55	7.21	7.15	7.40	7.67	5.00
Arg	6.50	6.42	6.43	6.66	6.47	6.35	6.00

### Analytical methods

Proximate analysis of diet, carcasses and faeces were made following the usual procedures: dry matter after drying in an oven at 104 °C for 24 h; ash by incineration at 550 °C for 12 h; protein (N x 6.25) by Kjeldahl method after acid digestion; energy in an adiabatic bomb calorimeter (Parr); diet and carcass fat after extraction by the Soxhlet method; starch in the diets and faeces by the enzymatic method (Thivend *et al*, 1972) using glucoamylase and glucose oxidase; chromic oxide in diet and faeces according to Bolin *et al* (1952). Dietary amino acid analyses were made after acid hydrolysis (HCl 6N, 110 °C, 24 h) of samples and ion-exchange chromatography.

Total plasma free amino acids (as meq glycine equivalents) released by ninhydrin reaction (Spies, 1957) and glucose were measured enzymatically (Sigma Kit, No 510). Statistical analyses (analyses of variance followed by Duncan's multiple range test) were made following procedures outlined by Snedecor and Cochran (1956).

### RESULTS

#### Growth performance and food utilization

Reported in table III are the results on growth performance and nutrient utilization efficiencies. Live body weight gain was significantly higher ( $P < 0.01$ ) in all experimental batches than in fish fed the commercial diet. Within the experimental groups, the best results were observed in fish fed high levels of cooked *triticale* (CT<sub>30</sub>) as well as in those fed the diet containing the lowest level of native *triticale* (T<sub>10</sub>). A significant decrease in weight gain ( $P < 0.01$ ) was observed in fish fed diets containing 20 and 30% of untreated *triticale* (diets T<sub>20</sub> and T<sub>30</sub>). Feed: gain (FGR = dry feed intake/live weight gain) and protein efficiency ratios (PER = live weight

**Table III.** Growth performance and nutrient utilization efficiencies in rainbow trout fed different levels of native and cooked *triticale*<sup>1</sup>. (1) Figures with different superscripts are significantly different from each other ( $P < 0.05$ ). (2) Feed intake/weight gain. (3) Protein efficiency ratio = weight gain/protein intake. (4) Specific growth rate =  $100 \times ((\ln wf - \ln wi)/t)$  where  $w_i$  and  $w_f$  are initial and final weights and  $t$  the duration in days of the trial. (5) Retention as % of dietary intake.

Diets	$T$	$T_{10}$	$T_{20}$	$T_{30}$	$CT_{20}$	$CT_{30}$	$C$
Initial mean weight (g)	100.7 <sup>a</sup>	102.7 <sup>a</sup>	100.8 <sup>a</sup>	101.4 <sup>a</sup>	99.9 <sup>a</sup>	99.2 <sup>a</sup>	104.1 <sup>a</sup>
Final mean weight (g)	220.2	226.0	213.3	215.4	217.1	222.9	189.9
Weight gain (g)	119.5 <sup>a</sup>	123.3 <sup>a</sup>	112.5 <sup>b</sup>	114.0 <sup>b</sup>	117.2 <sup>a</sup>	123.7 <sup>a</sup>	85.8
Feed: Gain ratio <sup>2</sup>	1.32 <sup>ab</sup>	1.22 <sup>b</sup>	1.29 <sup>ab</sup>	1.44 <sup>b</sup>	1.26 <sup>ab</sup>	1.19 <sup>a</sup>	1.48
PER <sup>3</sup>	1.78 <sup>a</sup>	1.79 <sup>a</sup>	1.70 <sup>a</sup>	1.50 <sup>b</sup>	1.75 <sup>a</sup>	1.84 <sup>a</sup>	1.41
SGR <sup>4</sup>	1.50	1.52	1.44	1.44	1.50	1.55	1.15
Protein retention (%) <sup>5</sup>	38.6 <sup>a</sup>	38.3 <sup>a</sup>	35.9 <sup>bc</sup>	32.0 <sup>c</sup>	38.2 <sup>a</sup>	37.8 <sup>ab</sup>	38.4
Energy retention (%)	42.4 <sup>a</sup>	40.1 <sup>a</sup>	39.7 <sup>a</sup>	35.2 <sup>b</sup>	40.4 <sup>a</sup>	41.2 <sup>a</sup>	36.5

gain/protein intake) were significantly affected in trout fed diets containing 30% of native *triticale*.

Protein and energy retention efficiencies were also variably affected by the dietary treatments. In those fish fed cooked *triticale* containing diets, both energy and protein retention efficiencies were comparable to that observed for fish fed the control diet. Inclusion of uncooked *triticale* at above 20% in the diet (diets  $T_{20}$  and  $T_{30}$ ) led to a decrease in protein retention efficiency whereas energy retention was significantly ( $P < 0.01$ ) reduced in those fish fed diet  $T_{30}$ .

### Carcass composition

The hepatosomatic index (liver wt/live body wt  $\times 100$ ) was lower in rainbow trout fed diets  $T_{20}$  and  $T_{30}$  with high levels of incorporation of native *triticale* (table IV).

The protein, fat and energy contents of whole and eviscerated fishes were little affected by dietary treatments.

### Apparent digestibility coefficients (ADC)

ADC values for dry matter were significantly lower ( $P < 0.01$ ) for diets  $T_{20}$  and  $T_{30}$  than for the other experimental diets but were comparable to that of the commercial diet (table V). These differences were also reflected in the digestibility of energy of the different diets. ADC values for starch in diets containing precooked *triticale* ( $CT_{20}$  and  $CT_{30}$ ) was above 90%, significantly higher than those of diets with native *triticale*. Besides, there was a significant decline (from 78–54%) in the digestibility of dietary starch with increasing levels of native *triticale* in the diets. No significant differences were observed in the ADC of pro-

**Table IV.** Initial and final composition of rainbow trout fed different levels of native and cooked *triticale* <sup>1</sup>. <sup>1</sup> Figures with different superscripts are significantly different from each other ( $P < 0.01$ ). <sup>2</sup> Hepato somatic index = wt of liver/live body weight x 100.

	<i>Initial</i>	<i>T</i>	<i>T</i> <sub>10</sub>	<i>T</i> <sub>20</sub>	<i>T</i> <sub>30</sub>	<i>CT</i> <sub>20</sub>	<i>CT</i> <sub>30</sub>	
<i>Whole fish</i>								
Dry matter (%)	27.7	32.4	33.3	32.2	33.3	33.2	32.5	NS
Protein (% DM)	55.3	54.3	52.6	53.4	52.1	53.2	52.4	NS
Fat (% DM)	36.6	36.4	37.1	37.1	37.1	37.8	37.7	NS
Energy (kJ/g DM)	25.8	26.0	26.9	26.0	25.1	25.4	25.6	NS
HSI (%) <sup>2</sup>	1.33	2.19 <sup>a</sup>	2.01 <sup>a</sup>	1.63 <sup>b</sup>	1.69 <sup>b</sup>	2.24 <sup>a</sup>	2.14 <sup>a</sup>	**
<i>Eviscerated fish</i>								
Dry matter (%)	23.1	30.3	29.8	30.1	29.9	31.6	31.7	NS
Protein (% DM)	61.6	61.3	59.7	59.2	59.0	57.6	58.7	NS
Fat (% DM)	29.8	29.1	31.3	32.9	31.5	33.5	32.8	NS
Energy (kJ/g DM)	24.6	25.1	25.5	25.7	24.0	24.9	25.1	NS
<i>Viscera</i>								
% body weight	11.3	12.6	12.0	12.3	11.6	12.6	12.3	NS
Dry matter (%)	48.7	46.6	46.7	46.9	49.8	44.5	43.6	NS

tein of the different experimental diets. On the basis of data on intake, digestibility and carcass composition, a tentative energy budget was made which is reported in table VI. It is clear that inclusion of cooked *triticale* improved energy retention per unit DM intake.

### **Blood metabolites**

Post-prandial glucose levels in plasma presented slightly different patterns of changes depending on the dietary level and quality of *triticale* (table VII). The pre-feeding level was reached by 24 h after

**Table V.** Apparent digestibility coefficients (ADC) of the test diets (%)<sup>1</sup>. (1) Figures with different superscripts are significantly different from each other ( $P < 0.05$ ).

<i>Diets</i>	<i>T</i>	<i>T</i> <sub>10</sub>	<i>T</i> <sub>20</sub>	<i>T</i> <sub>30</sub>	<i>CT</i> <sub>20</sub>	<i>CT</i> <sub>30</sub>	<i>C</i>
Dry matter	73.9 <sup>a</sup>	72.3 <sup>a</sup>	64.5 <sup>b</sup>	62.7 <sup>b</sup>	74.0 <sup>a</sup>	75.3 <sup>a</sup>	62.5
Protein	85.7	86.3	84.4	84.8	87.7	89.2	85.8
Energy	85.1 <sup>a</sup>	83.4 <sup>a</sup>	77.1 <sup>be</sup>	75.2 <sup>b</sup>	85.2 <sup>a</sup>	86.7 <sup>a</sup>	79.2
Starch	94.3 <sup>a</sup>	77.9 <sup>b</sup>	58.2 <sup>c</sup>	54.2 <sup>d</sup>	90.9 <sup>e</sup>	93.6 <sup>ae</sup>	--

**Table VI.** Gross (GE), digestible (DE), metabolizable (ME) and net energy (NE) values of the diets (kJ/g DM intake). GE = Gross energy; DE = Digestible energy; ME (Metabolizable energy) = DE - NFEL; NFEL (Non-fecal energy loss) = NFNL x 25 kJ/gN (as per Elliott and Davidson, 1975) where NFNL (non-fecal nitrogen loss) : Digestible N - Retained N; NE (Net energy) = ME - HiE where HiE (heat increment of feeding) = Digestible N x 28 kJ/gN (as per Cho *et al.*, 1982); RE = Retained energy.

	<i>T</i>	<i>T</i> <sub>10</sub>	<i>T</i> <sub>20</sub>	<i>T</i> <sub>30</sub>	<i>CT</i> <sub>20</sub>	<i>CT</i> <sub>30</sub>
GE	20.6	20.5	20.6	20.6	20.7	20.9
DE	17.5	17.1	15.9	15.5	17.6	18.1
ME	16.7	16.2	15.0	14.5	16.7	17.1
NE	14.9	14.5	13.3	12.8	15.0	15.4
RE	8.7	8.2	8.2	7.2	8.4	8.6

meals only in those trout fed the diet containing 10% *triticale* and to a certain extent in those fed the control diet (diet *T*). In trout fed higher levels of *triticale* (both native and cooked), plasma glucose levels were relatively higher even 24 h after the meal.

The concentration of free amino acids in plasma increased after feeding with peak

levels between 6 and 9 h after meal in all groups. However, only in those fish fed cooked *triticale* (batches *CT*<sub>20</sub> and *CT*<sub>30</sub>) was there a definite diurnal pattern as was the case 24 h after the meal, the levels were comparable to the pre-feeding levels. The amplitude of changes were not different between fish fed the different experimental diets (table VIII).

**Table VII.** Post-prandial development of plasma glucose in trout fed different levels of native and cooked *triticale*<sup>1</sup> (in mg/100 ml). (1) Means with standar errors (*n* = 3) are given. Zero h corresponds to 9 am. Fasted control value = 67.7±7.0 mg/100 ml.

Hours after meal	<i>T</i>	<i>T</i> <sub>10</sub>	<i>T</i> <sub>20</sub>	<i>T</i> <sub>30</sub>	<i>CT</i> <sub>20</sub>	<i>CT</i> <sub>30</sub>
0	77.3 ± 21.4	89.3 ± 12.5	93.6 ± 6.6	90.7 ± 9.6	69.3 ± 27.6	69.5 ± 9.8
3	139.0 ± 12.8	94.5 ± 5.4	133.0 ± 11.9	125.2 ± 9.4	99.5 ± 12.8	99.2 ± 0.3
6	143.8 ± 10.9	133.4 ± 12.6	143.8 ± 27.4	123.0 ± 18.7	133.4 ± 21.7	112.1 ± 31.3
9	109.4 ± 5.1	138.9 ± 20.1	133.9 ± 25.1	140.4 ± 18.9	169.9 ± 12.1	160.6 ± 10.5
12	162.4 ± 3.5	156.2 ± 11.6	143.4 ± 20.7	168.1 ± 25.0	178.1 ± 42.1	150.5 ± 16.9
24	112.4 ± 11.3	89.5 ± 5.1	160.0 ± 18.9	154.6 ± 25.0	169.8 ± 8.6	163.6 ± 8.9

**Table VIII.** Post-prandial development of plasma free amino acids in trout fed different levels of native and cooked *triticale*<sup>1</sup> (in mM equiv/glycine). <sup>1</sup> Means with standard errors ( $n = 3$ ) are given. Zero hour corresponds to 9 am.

Hours after meal	T	T <sub>10</sub>	T <sub>20</sub>	T <sub>30</sub>	CT <sub>20</sub>	CT <sub>30</sub>
0	1.24 ± 0.3	2.35 ± 0.7	2.38 ± 1.1	1.99 ± 0.7	1.32 ± 0.5	1.32 ± 0.2
3	2.88 ± 0.6	2.63 ± 0.5	3.30 ± 0.1	3.82 ± 0.5	4.03 ± 1.1	3.73 ± 1.0
6	5.43 ± 0.7	4.27 ± 0.6	5.04 ± 0.2	5.65 ± 1.1	5.19 ± 0.5	5.37 ± 1.5
9	4.16 ± 0.5	4.73 ± 1.1	7.85 ± 0.8	3.14 ± 0.7	5.03 ± 2.0	2.99 ± 0.9
12	3.78 ± 0.7	4.19 ± 0.5	3.99 ± 1.5	3.61 ± 0.1	4.1 ± 1.7	3.92 ± 1.6
24	3.98 ± 0.2	4.61 ± 0.8	3.79 ± 0.1	4.77 ± 1.1	1.71 ± 0.1	1.87 ± 0.5

## DISCUSSION

The nutritive value of *triticale* for higher animals has been studied to a great extent (Bourdon and Perez, 1982; Perez and Bourdon, 1986). One of the interesting features of this cereal for terrestrial animal feeds is its relatively high lysine content (Davies, 1989). In the present trial with rainbow trout, the protein and amino acid composition of *triticale* only had minor significance since fishmeal was the major source of these essential nutrients. Besides, as can be seen in table II, in all the experimental diets, requirements for all essential amino acids of salmonids were met.

Incorporation of up to 30% of cereals in rainbow trout diets did not appear to exert any adverse effects on growth performance provided the cereal was submitted to a thermal treatment. In fact, inclusion of 20 and 30% of native *triticale* in trout diets led to some negative effects on selected growth parameters, in accordance with many previous observations on the effects of crude starch incorporation in salmonid diets (Edwards *et al*, 1977; Refstie and Austreng, 1981; Hilton *et al*, 1987). On the

other hand, with diets containing cooked *triticale*, growth of rainbow trout was comparable to those fed the control diet, supporting similar results obtained earlier by Bergot and Breque (1983) and Kaushik *et al* (1989).

The changes in hepatosomatic indices (HSI) were comparable to those observed by Refstie and Austreng (1981) in rainbow trout fed high carbohydrate diets. Thermal treatment of cereals made more digestible energy available and led to an increase in the HSI of rainbow trout with values comparable to those observed in fish fed the control diet containing dextrin. Inclusion of native *triticale* decreased the digestible energy level and consequently the hepatosomatic indices were also affected by changes in the availability of starch. Dressed weights were not found to be affected by dietary starch levels in rainbow trout by Bergot (1979), but our results on viscero-somatic indices were slightly higher than those observed by the latter author. The changes in dry matter content of viscera and in eviscerated fish can explain the differences observed in protein and fat contents of groups fed diets containing more digestible carbohydrates; the same



type of variation was observed by Bergot (1979).

The decrease in the ADC of dry matter with increasing levels of inclusion of native *triticale* corresponds to an increase in the amount of crude starch provided by the cereal. It is known that the digestibility of starch decreases with the level of crude starch inclusion in trout diets (Singh and Nose, 1967; Rychly and Spannhof, 1979). This leads to a direct change in the amount of digestible energy made available to rainbow trout as has already been demonstrated by several previous works (Rychly and Spannhof, 1979; Hilton *et al.*, 1982; Spannhof and Plantikow, 1983). The positive effect of starch gelatinization was clearly demonstrated with the higher digestibility coefficients observed (> 90%) for diets containing cooked *triticale* with data comparable to diets containing dextrin. The DE values were then clearly improved when *triticale* was cooked. Protein digestibility is little affected by carbohydrate content of the diets (Reftsie and Austreng, 1981) and this was also evident from our results. The better protein retention efficiencies observed in fish fed diets containing cooked *triticale* can be explained by a decrease in nitrogen excretion in response to an increase in dietary non-protein digestible energy (Kaushik and Oliva Teles, 1985). This improvement cannot be explained by any depression in feed intake with diets high in digestible carbohydrates, as the level of feed intake was maintained constant in all batches during the experiment. No evidence is obtained for the probably high alpha-amylase activity suggested in *triticale* by Falisse (1980).

On the basis of results obtained on the ADC of different experimental diets, we can estimate the dry matter digestibility of native and cooked *triticale* to be 40 and 74% respectively, but more specific work will be necessary to confirm these values.

The post-prandial development of plasma glucose concentrations is known to be dependent upon the source and level of carbohydrates (Bergot, 1979; Kaushik and Oliva-Teles, 1985). These studies have shown that in fish fed diets containing crude starch, there is generally a low increase in the postprandial glycemia levels than in those fed pre-treated starch or glucose. In the present study, although the basal level found in fasted fish (68 mg glucose/100 ml) was comparable to earlier observations by Kaushik and Oliva-Teles (1985), the frequency of blood sampling was not adequate enough to demonstrate clear patterns of changes in fed fish as shown in earlier studies. Besides, the method involved in the analysis of plasma glucose was also different from the one used in the above cited works. However, sustained peak levels were only observed in those fish fed cooked *triticale* in comparison to those fed native *triticale*.

The post-prandial increase in plasma free amino acid levels depends to a large extent on the dietary protein intake. However, in some studies, it was shown that the post-prandial patterns could be affected by the quality of dietary starch. Kaushik and Oliva-Teles (1985) found a slower rate of increase in the free amino acid levels in fish fed crude starch in comparison to those fed gelatinized starch. Increased glycemia is also known to provoke a decrease in free amino acid levels in plasma (Palmer and Ryman, 1972) and our results do show such a decrease in plasma free amino acids in fish fed high levels of cooked *triticale*. It is worth noting that the post-prandial pattern of changes in plasma total free amino acid levels is affected by the quality of *triticale* included in the diet. Whether such differences in the overall patterns also reflect changes in individual amino acid levels requires further study.

## CONCLUSION

*Triticale* appears to be a promising ingredient for inclusion in rainbow trout diets provided it is subject to preliminary thermal treatment in order to increase the level of available energy.

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