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NITROGEN AND ENERGY UTILIZATION BY *OREOCHROMIS MOSSAMBICUS* FINGERLINGS FED DIETS CONTAINING GRADED LEVELS OF BREWERY DRAFF

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ABSTRACT

Duplicate groups of 15 *Oreochromis mossambicus* fingerlings (1 g) were fed with each of four isonitrogenous (36% crude protein) and isocaloric (20 kJ/g) diets in eight 15 l aquaria for nine weeks. The diets contained soybean meal, ground corn, fishmeal, and brewery draff and were formulated in such a way as to have fishmeal : brewery draff ratio of 20 : 0 (diet DB0), 20 : 15 (diet DB15), 20 : 30 (diet DB30v), and 13 : 30 (diet DB30a) respectively. In diets DB15 and DB30v, plant proteins were replaced by 15 and 30% of brewery draff. In diet DB30a, 30% brewery draff replaced part of the fishmeal. Although feed : gain ratios varied from 1.34 for diet DB0 to 1.54 for diet DB30a no significant difference ($p > 0.05$) was noticed. Carcass analysis revealed a significant decrease ($p < 0.05$) in lipid and energy content from diets DB0 to diet DB30a. Excreted nitrogen and digestible protein : digestible energy ratios were correlated ($r = 0.70$, at $p < 0.05$). Based on growth performance, nutrient retention efficiencies, and nitrogen and energy balance, brewery draff appears to be a viable partial dietary protein source for tilapia.

Lack of nutritionally adequate and low-cost feeds has been one of the constraints to the development of intensive culture of tilapia in many developing countries. The traditional market value of fish and fish products in Africa south of the Sahara region is usually low (Satia, 1989). This limits the use of relatively expensive feed ingredients in production. It is hence essential to investigate the use of inexpensive agricultural by-products in tilapia feeds, preferably those locally available and unsuitable for direct human consumption.

Considerable work has been reported on the subject, mainly focussing on the replacement of fishmeal, an expensive and relatively scarce feed ingredient, by some alternative sources. These studies show that more than one-third of fishmeal in complete diets of tilapia can be replaced by feed ingredients such as brewery yeast, seaweed, and miscellaneous leaves and seeds without affecting

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fish growth (Cruz and Laudencia, 1978; Jackson *et al.*, 1982; Viola and Arieli, 1983; Tacon *et al.*, 1983; Appler and Jauncey, 1983; Gaigher *et al.*, 1984; Appler, 1985; Shiau *et al.*, 1987; Wee and Wang, 1987; Davies and Warcham, 1988; Martinez-Palacios *et al.*, 1988; Olvera *et al.*, 1988).

In Cameroon, Central Africa, brewery draff, a by-product of the beer industry, is available in large quantities. In 1988, about 100,000 t of this material was produced from the dozen beer factories in Cameroon, only a small quantity of which is currently used by farmers.

Brewery draff essentially consists of cellulose husks of malt (artificially sprouted barley seed) on which are stuck inner parts which have not been made soluble during the brewing process. Morrison (1956) and Piccioni (1965) reported the chemical composition of brewery draff and gave information on its current use in livestock feeds. Due to its positive effect on milk production, it has been recommended for milch cows in fresh condition. Dried, it can completely replace wheat bran in layer diets provided the fibre content is not too high (20%). The stimulating effect of brewery draff on the appetite of animals has also been recorded. In an experiment in which aqueous extracts of brewery draff were injected intravenously into ewes and cows, Sawadogo *et al.* (1989) showed that this feed ingredient contained a factor stimulating the secretion of prolactin and growth hormone.

However, few studies have been carried out on the use of brewery draff in fish feed. In the Central African Republic, De Kimpe (1971) registered a feed : gain ratio (FGR) of 12.6 while feeding *Oreochromis niloticus* with fresh brewery draff in earthen ponds; when draff was incorporated dry in more balanced diets for *O. niloticus* and *Clarias lazera* reared together, the FGR was 1.26.

At the Landjia fish culture station (Central African Republic), Tognama-Mbona and Janssen (1985) reported the following data while rearing *O. niloticus* fingerlings (10 g) in aquaria with diets containing 20% of brewery draff: daily growth rate 0.2 g/day; FGR 2.1; cost of production of 1 kg of fish 338 FCFA; when 40% brewery draff was incorporated in diets, FGR rose (2.3) and the daily growth rate decreased. The authors attributed the later results to the possible poor digestibility of brewery draff which contained 22% fibre, but they did not further investigate the matter.

Tilapia are much appreciated as table fish in Africa, and they are capable of converting low quality inexpensive feeds into high quality proteins more efficiently than other warm-water species (Pullin, 1988). In Cameroon, the use of single agro-industrial by-products such as rice bran or cotton seed meal in tilapia farming is common, but commercial supplemental feeds are not available. The present study was initiated as a preliminary approach in the evaluation of brewery draff as a substitute for fishmeal or other more costly ingredients in complete tilapia diets, the main objective being to determine the maximum inclusion rate of brewery draff still allowing reasonable growth of the fish. Some attempts were made also to estimate the digestibility of brewery draff by tilapia.

MATERIALS AND METHODS

Experimental system and animals

The rearing system consisted of eight 15 l aquaria filled with tap water. Each aquarium was equipped with a 7 W immersion heater to maintain the temperature at 28° ± 1°C, a 6 W air pump to keep the level of dissolved oxygen over 90% saturation, a 3 W filter allowing a complete renewal of water every 5 min., and a 60 W overhead fluorescent lamp scheduled to provide light every day from 0800 to 2000 hours. A 10 cm sand layer was provided at the bottom of each aquarium. Dissolved oxygen (digital CG 867 oxymeter), temperature, pH, and ammonia nitrogen and nitrites (HACH kit dr/2-el spectrophotometer) were monitored regularly.

Oreochromis mossambicus juveniles were produced in the laboratory from the simultaneous spawning of five females. At the start of the experiment, the fish were 22 days post-release and weighed 1.1 ± 0.5 g ($p < 0.05$).

The feeding trial was conducted over nine weeks. Two weeks prior to the experiment, 17 fish per tank were acclimatized to their rearing environment, and received a commercial trout ration (Aqualim). At the start of the trial, two fish per aquarium were removed for proximate carcass analysis; each experimental diet was then randomly allotted to duplicate sets of 15 fish each. Fish were anaesthetized with phenoxyethanol (0.1 ml/l) and individually weighed and measured at the start of the experiment and subsequently fortnightly, with no feed being provided on the eve of the weighing day. Water was changed and the rearing system carefully cleaned on that day. At the end of the experiment, all fish were sexed and three males and four females withdrawn from each tank for proximate carcass analysis.

Diets and feeding regime

The diets contained fishmeal, soybean meal, corn, and brewery draff. The latter was collected from a beer factory at Puyoo (Landes, 40, France). Based on the results of proximate analysis of these ingredients (Table 1), the diets were formulated to provide 36% crude protein, 8% crude lipid, and 20 kJ/g gross energy, with varying proportions of brewery draff in the diet from 0 to 30% as a substitute to other ingredients (Table 2). In two experimental diets (DB15 and DB30v), fishmeal level was comparable to the control diet (DB0) and brewery draff replaced part of the plant protein. In the fourth diet (DB30a), part of fishmeal was replaced by brewery draff.

The dry ingredients were sieved (1.25 mm sieve) and mixed with oil in a laboratory mixer while cold water was added until a stiff dough resulted. This was then passed through a meat mincer (Simon-Heese) with a 2.3 mm die and the resulting spaghetti-like strings were dried in a forced convection-air dryer at 38°C for 48 hr. After drying, the diets were manually broken into 1 mm size pellets. Every aquarium as previously described was provided with an automatic feeder to distribute the respective diets at 6% of live weight per day in six equal meals.

Table 1. Proximate analyses of feed ingredients and their amino acid composition

Components	Ingredients			
	Brewery draff	Soybean meal	Ground maize	Fish meal
Moisture	6.4	14.7	12.2	10.9
Crude protein (N × 6.25), % dry matter	26.6	52.6	9.2	68.3
Crude lipid, % dry matter	11.1	2.7	4.2	12.3
Ash, % dry matter	3.7	7.4	1.47	15.7
Gross energy (kJ/g dry matter)	21.2	19.6	19.1	21.0
Amino acids (g/16 g N)				
Alanine	4.3	4.5	8.7	6.4
Arginine	3.9	8.3	5.1	6.1
Aspartic acid	7.7	10.8	6.3	7.9
Glutamic acid	22.0	18.0	20.4	12.6
Glycine	2.9	4.4	4.9	5.6
Histidine	1.2	3.3	2.6	1.5
Isoleucine	2.9	5.0	4.1	4.9
Leucine	7.6	8.1	12.1	8.6
Lysine	3.6	6.5	3.0	6.8
Methionine	1.3	1.8	1.9	2.5
Phenylalanine	5.7	4.8	3.7	4.7
Serine	3.7	5.8	4.5	3.7
Threonine	2.9	3.7	3.0	3.7
Tyrosine	3.4	3.8	3.9	3.0
Valine	3.8	5.1	4.5	5.7

After every fortnightly weighing, ration sizes were adjusted according to body weights for the next period.

Faeces collection

On weeks 4 and 5 of the trial, the sand, was removed from the bottom of the aquaria. Fish received their usual six meals, and deposited faeces were removed from 1200 to 1300 hours and 1800 to 1900 hours using a tap water siphoning system; faeces collected were then filtered on fine mesh and transferred to petri dishes for drying and stored at −20°C until analysis. The filtering process was conducted very slowly so as to prevent losses through leaching.

Ammonia nitrogen excretion

In view of establishing the nitrogen balance, metabolic excretory losses (branchial and urinary) were estimated by measuring ammonia nitrogen excreted by fish maintained under static water conditions. Two days prior to the end of the experiment, the filters were stopped in the aquaria and total nitrogen accumulated was measured every hour over a 24 hr period. In the absence of facilities for the continuous quantification of ammonia and urea N excretion (Kaushik, 1980), we resorted to measurement under static conditions, which had been used by others with rainbow trout (Rychly and Marina, 1977).

Table 2. Composition of experimental diets (% dry matter)

Ingredients	Diets			
	DB0	DB15	DB30v	DB30a
Fishmeal (herring)	20	20	20	13
Soybean meal	35	32	30	40
Ground maize	38	27	15	11
Brewery draff	0	15	30	30
Vitamin mix[1]	2	2	2	2
Mineral mix[2]	1	1	1	1
Soybean oil	3	2	1	2
Chromic oxide	1	1	1	1
Proximate analysis (dry matter basis)				
Crude protein, %	35.3	36.7	38.6	38.8
Crude fat, %	8.2	7.7	8.4	8.2
Ash, %	8.1	8.2	8.4	8.0
Gross energy, kJ/g	19.7	20.1	20.2	20.5
Amino acids, g/16 g N				
Alanine	5.3	6.0	5.2	5.1
Arginine	6.2	6.8	6.2	7.2
Aspartic acid	11.1	10.7	10.5	11.0
Glutamic acid	17.9	18.0	20.8	18.3
Glycine	5.3	5.5	5.1	4.9
Histidine	1.8	1.9	1.8	2.0
Isoleucine	4.6	4.6	4.5	4.9
Leucine	7.9	7.8	8.0	8.3
Lysine	10.7	10.1	11.7	8.6
Methionine	1.4	2.1	1.8	1.3
Phenylalanine	5.0	5.0	5.1	5.2
Serine	4.6	5.3	4.5	4.1
Threonine	3.7	4.0	3.7	4.1
Tyrosine	4.2	4.5	4.1	4.5
Valine	4.8	4.9	4.8	5.1

[1]Vitamin mix contains (g/kg of mix): vit A 500,000 IU/g 1.5, vit D3 100,000 IU/g 1.5, vit E 500 IU/g 6.0 vit K 0.25, thiamine 0.75, riboflavin 1.5, pyridoxine 0.75, nicotinic acid 8.75, ascorbic acid 25.0, folic acid 0.25, vit B12 1 g/kg 2.5, inositol 50.0, biotine 2% 6.25, calcium panthothenate 2.5, choline 50% 200, cellulose (Durieux) 692.5.

[2]Mineral mix contains (g/kg of mix): calcium carbonate 215.0, magnesic hydrate 124, potassium chloride 90.0, iron citrate 20.0, copper sulfate 3.0, zinc sulphate 4.0, manganese sulphate 3.0, bicalcic sulphate 500.0, sodium chloride 40.0, potassium iodine 0.04, cobalt sulphate 0.02.

Analytical procedures

Feed ingredients and experimental diets were ground beforehand and sifted through a 1 mm mesh. Faeces and fish were freeze-dried before analysis. All analyses were run on duplicate samples and value converted to dry basis. Dry matter was determined by difference after desiccation at 105°C for 24 hr. Ash was deducted by difference after burning the dry sample in a muffle furnace at 550°C for 24 hr. Crude protein (N × 6.25) was measured by Kjeldahl method (AOAC, 1975). Amino acids were measured by the C18 reversed phase chromatography (Rosset *et al.*, 1982) in a Varian 500 chromotograph after acid hydrolysis (HCl 6N, 110°C, 24 hr). Crude fat was determined by the Folch method (Folch *et*

al., 1957). Gross energy content was determined by direct calorimetry (adiabatic bomb calorimeter, Gallenkamp CB 100). The concentration of the indicator in faeces was measured spectrophotometrically after acid digestion by the method of Furukawa and Tsukahara (1966).

Calculation and statistical analysis

Feed : gain ratio, protein efficiency ratio (PER) (Osborne *et al.*, 1919), specific growth rate (SGR) (Brown, 1957), apparent digestibility coefficient (ADC) (Maynard and Loosli, 1969), retention efficiencies, and energy and nitrogen budgets (Cho and Kaushik, 1985) were computed. Statistical analyses were performed using the SAS statistical package (SAS, version 6). Data were subjected to an analysis of variance and Duncan multiple-range test was used to evaluate specific differences between treatments (significance level: 0.05). Linear regression was used to evaluate the relationship among some parameters (Snedecor and Cochran, 1957).

RESULTS

Mean water quality parameters, with few variations within and between aquaria during the monitoring period, were as follows: temperature 28°C; dissolved oxygen 8 mg/l, pH 6.9; ammonia nitrogen 0.02 mg/l; nitrite less than 0.1 mg/l. Only one fish died throughout the experiment.

Growth and feed utilization

Final average weight varied from 5.6 to 7.4 g with no significant difference ($p > 0.05$) between the treatments. Mean daily growth rate and mean SGR were fairly constant for all diets, diet DB0 being however significantly higher ($p < 0.05$) than diet DB30a (Table 3).

All fish readily accepted their ration and fed aggressively for the duration of the experiment. Until week 9, when spawning started to be registered in all aquaria, no uneaten food was observed. Diet DB0 was consumed significantly more ($p < 0.05$) than the others. The FGR (Table 3) varied from 1.34 (DB0) to 1.54 (DB30a), but the differences were not significant ($p > 0.05$). The PER decreased with increasing level of incorporation of brewery draff in the diet, with significant difference ($p < 0.05$) between diets DB0 and DB30a.

Body composition

The carcass composition (Table 4) was not much affected by dietary brewery draff levels. Moisture and crude lipid contents were inversely related ($r = 0.97$, significant at $p < 0.01$). The fish fed the control diet (DB0) had significantly higher ($p < 0.05$) gross energy content than those fed diet DB30a.

Table 3. Growth performance and feed utilization parameters for the tilapia *O. mossambicus* fed different experimental diets over nine weeks

	Diets				
	DB0	DB15	DB30v	DB30a	MSE
Initial wt, Wi (g)	1.1[a]	1.1[a]	1.1[a]	1.1[a]	0.44
Final wt, Wf (g)	7.4[a]	6.1[a]	6.0[a]	5.6[a]	3.09
SGR (%/day)	3.0[a]	2.7[ab]	2.7[ab]	2.6[b]	0.02
DGR (g/fish/day)	0.10[a]	0.07[ab]	0.07[ab]	0.07[b]	0.00
Feed intake (g dry matter/fish)	8.1[a]	7.1[a]	6.8[c]	7.1[b]	0.07
FGR	1.34[a]	1.41[a]	1.40[a]	1.54[a]	0.01
PER	2.12[a]	1.94[ab]	1.85[ab]	1.63[b]	0.03
Nutrient retention efficiencies					
Protein (% crude protein intake)	32.6[a]	29.6[a]	26.7[a]	24.2[a]	11.00
(% digestible protein intake)	(37.0)	(35.5)	(32.0)	(29.2)	
Fat (% intake)	73.5[a]	71.6[a]	54.6[b]	43.1[b]	32.01
Energy (% gross energy intake)	25.0[a]	22.7[a]	20.2[ab]	16.1[b]	4.79

SGR = 100 (log Wf - log Wi)/growth period
DGR = (Wf – Wi)/growth period
FGR = dry feed intake/weight gain
PER = weight gain/protein intake
MSE = mean square of error in the analysis of variance; figures in each line having different superscripts are significantly different ($p < 0.05$) from each other.

Table 4. Gross body composition (% wet wt) of the tilapia *O. mossambicus* fed different experimental diets for nine weeks

		Diets				
Components	Initial	DB0	DB15	DB30v	DB30a	MSE
Moisture	77.4	74.3[a]	73.7[a]	75.6[a]	76.3[a]	1.84
Protein	13.5	14.6[a]	14.9[a]	14.2[a]	14.6[a]	0.17
Fat	4.8	7.3[a]	7.3[a]	6.3[a]	6.1[a]	0.42
Ash	3.9	3.4[a]	3.7[a]	3.4[a]	3.2[a]	0.08
Gross energy (kJ/100 g wet weight)	4.5	6.07[ab]	6.09[a]	5.5[ab]	5.1[b]	0.08

Figures in each line having the same superscript are not significantly different ($p > 0.05$) from each other.

The final body weights and body composition of male and female fish are reported in Table 5. Males grew 1.4 times faster than females, and crude protein and ash contents in the whole body of males were significantly higher ($p < 0.05$) than those of female tilapia.

Nutrient utilization

Nutrient retention efficiencies were calculated from the carcass analysis data presented in Table 4 and are shown in Table 3. Protein retention efficiency decreased with increasing level of brewery draff in the diet. Lipid and energy retention followed the same trend. Lipid retention efficiency was significantly higher

Table 5. Growth and body composition of male and female *O. mossambicus*

	Female	Male	MSE
% of population	43.7[a]	56.3[a]	0.02
Average final weight (g)	5.14[b]	7.11[a]	1.93
Body composition (wet basis)			
Moisture, %	74.3[a]	75.0[a]	2.28
Protein, %	14.4[b]	14.9[a]	0.27
Fat, %	7.2[a]	6.1[a]	0.83
Ash, %	3.3[b]	3.8[a]	0.04
Energy, kJ/100 g	6.0[a]	5.6[b]	0.13

Figures in each column having the same superscript are not significantly different ($p > 0.05$).

($p < 0.05$) in fish fed the control diet than in those fed diets containing 30% brewery draff.

Digestibility

Faecal nitrogen losses were significantly higher ($p < 0.05$) between diets DB0 (12.8%) and DB30a (7.7%). The ADC of dry matter varied from 16% (DB30v) to 67% (DB0) and appeared to have been underevaluated. Protein digestibility varied as follows: DB0 88.1%; DB15 83.4%; DB30v 83.3%; DB30a 83.0%. These values were not related to the brewary draff content of the diet. The limited amount of faeces samples did not allow determination of lipid and energy digestibility.

Excreted nitrogen

Figure 1 shows the pattern of total ammonia nitrogen excretion over a 24 hr period. Three peaks were recorded: the first by 0200 hours, the second after the first meal (just preceded by the illumination of the aquaria), and the third after the last meal of the day (just followed by total darkness in the aquaria). Nitrogenous metabolic losses were evaluated respectively to be 0.53, 0.76, 0.79 and 0.67 g of nitrogen per kg of live weight per day for diets DB0, DB15, DB30v, and DB30a (Table 6). Since in teleosts nitrogen is not excreted in the form of ammonia alone, these losses are lower than those (respectively 0.96, 0.99, 1.08 and 1.25 g/kg/day) (Table 6) calculated by subtracting nitrogen retained in the carcass from digested nitrogen.

DISCUSSION

It appears from the results of this study that brewery draff can constitute 30% of tilapia diet without any depressive effect on fish growth and feed utilization.

In terms of growth and feed efficiency, the results registered are better than those of several earlier studies: Tognama-Mbona and Janssen (1985) fed nile tilapia (*O. niloticus*) juveniles (10 g) a pelleted diet containing 20% brewery draff and registered a SGR of 1.45%/day. When incorporating copra cake and *Leucaena* sp. (an algae) at 25% in a complete diet to feed tilapia fingerlings (30–50 g),

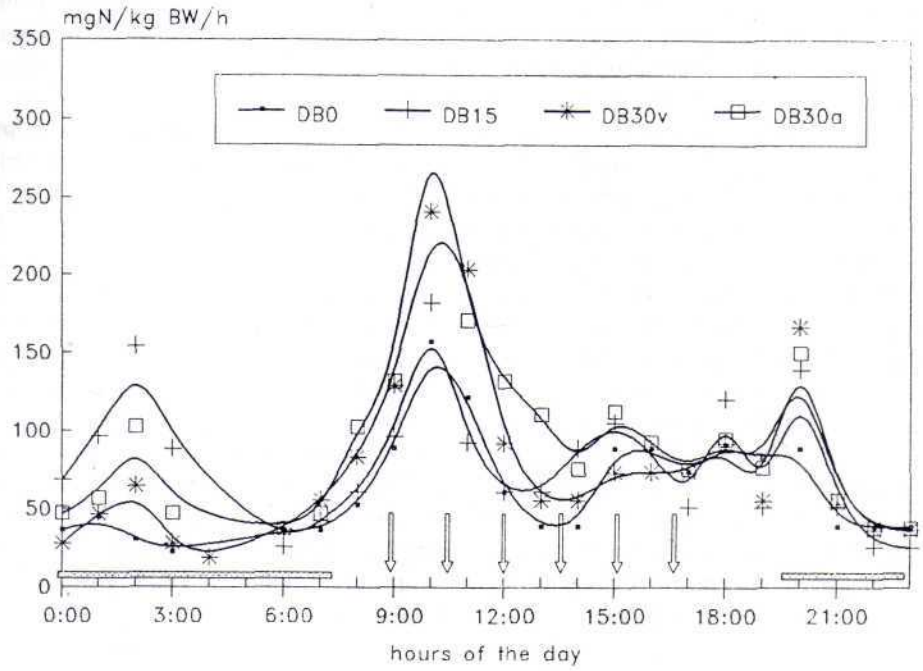

Fig. 1. Daily pattern of ammonia N excretion by *O. mossambicus* fed diets containing brewery draff. Shaded zone on the X axis corresponds to dark phase of the cycle. The arrows indicate meals. Water temperature 28° ± 0.5°C; pH 7.5 ± 0.2; oxygen levels 4 ppm.

Table 6. Nitrogen balance in tilapia fed different experimental diets (g N/kg live weight/day)

Components	Diets			
	DB0	DB15	DB30v	DB30a
Ingested nitrogen (IN)	1.72	1.85	1.91	2.13
Faecal nitrogen, FN	0.20	0.31	0.31	0.35
Digested nitrogen, DN (IN–FN)	1.52	1.54	1.59	1.77
Retained nitrogen, RN	0.56	0.55	0.51	0.52
Excreted nitrogen, EN	0.53	0.76	0.79	0.67
EN as % of IN	30.6	41.1	41.4	31.5
Calculated EN (DN–RN)	0.96	0.99	1.08	1.25

FN = from digestibility measurements.
RN = based on comparative carcass analyses (Table 4).
EN = Urinary N + branchial N, see Fig. 1.

Jackson *et al.* (1982) obtained SGRs of 1.11 and 0.34%/day respectively, 3 to 10 times lower than the present values. These results are all the more interesting as the substitution of fishmeal by brewery draff in the diet DB30a hardly affects fish growth and feed efficiency.

Underestimation of ADC can be attributed to leaching and contamination of

faeces with uneaten feed; this happened notwithstanding the care taken while using the faeces collection system adopted in this study. In order to avoid these events, it is evident that collectors developed at the INRA Fish Nutrition Laboratory by Choubert *et al.* (1982) should be used.

Several studies have shown that, once the requirements for all essential nutrients are met, efficiency of feed conversion by teleosts is more related to digestible protein : digestible energy ratio than to any other parameter. With Hanley's (1987) data on the ADCs of some feed ingredients, and based on the assumption that the ADCs are additive (Cho and Kaushik, 1985), digestible protein and energy of our experimental diets were calculated. Our observed values on digestible protein levels correspond well with calculated values. Based on this, the digestible protein : digestible energy ratios were found to vary from 22 to 29 mg of digestible protein per kJ of digestible energy (Table 7). Inclusion of brewery draff increases the ratio since its digestible protein content is high (62%) and its digestible energy is low (30%; Hanley, 1987). The ratios for the experimental diets were higher than the optimum level suggested by Hepher (1988); this means that when brewery draff is used as on ingredient in diets of juvenile tilapia, crude protein level lower than 36% is recommended. This observation is partly confirmed by data on nitrogen excretion which are related to digestible protein : digestible energy ratios ($r = 0.81$, significant at $p < 0.05$).

Table 7. Determined and calculated values for digestible protein (DP) and digestible energy (DE) of the experimented diets

Diets	DP (%)		DE (kJ/g DM)		DP/DE[2]
	obs.	calc.	obs.[1]	calc.	
DB0	31.1	30.9		13.8	22.4
DB15	30.6	31.7		12.5	25.4
DB30v	32.1	32.4		11.2	28.9
DB30a	32.2	33.0		11.4	28.9

[1]Digestible energy was not determined due to insufficient quantity of faeces collected.

[2]mg digestible protein/kJ digestible energy.

Assuming that starving tilapia consume 1.17 mg O_2/kg of live weight/day (Musisi, 1984) and that there is an energy expenditure of 25 kJ/g of excreted nitrogen (Elliott and Davison, 1975), the energy budget of the experimental diets was established. Table 8 shows that metabolizable and net energy slightly decreases when the brewery draff content of the diet increases. Shiau *et al.* (1989) showed that irrespective of fibre origin, intestinal transit of diet with high content of cellulose was low, with poor digestibility and low absorption of nutrient. The relatively slight decline in net energy with increasing level of brewery draff in the diets makes this ingredient very interesting. Against the needs established by Santiago and Lovell (1988) for *O. niloticus*, only methionine was possibly slightly limiting in the four diets, irrespective of the level of brewery draff in the diet (Table 2). It would have been interesting to study the effects of supplementary methionine. Studies

Table 8. Energy budget for *O. mossambicus* (Peters) fed the experimental diets (kJ/kg live weight/day) over nine weeks

	Dietary brewery draff level (%)			
	0	15	30v	30a
Measured components[1]				
Gross energy (GE)	601	635	624	700
Digestible energy (DE)	430	403	353	387
Retained energy (RE)	151	144	126	113
Maintenance expenses (EEF)	16	16	16	16
Calculated components[2]				
Non-faecal losses (UE = 25 × EN[3])	24	25	27	31
Metabolizable energy (ME = DE−UE)	406	378	326	256
ME as % of GE	67.6	59.5	52.5	50.9
ME as % of DE	94.4	93.8	92.3	92.0
Total heat produced (THP = ME−RE)	255	234	200	243
Heat increment of feeding (HiE = THP−EEF)	239	218	184	227
Net energy (NE = ME−HiE)	167	160	142	129

[1] DE = GE × ADC energy; RE: from Table 4; EEF = energy loss under fasting conditions.
[2] after Cho and Kaushik (1985).
[3] EN: excreted nitrogen (see Table 6).

on further decrease in fishmeal levels or total substitution of fishmeal by proteins of plant origin would also be of interest.

In conclusion, brewery draff can be considered as a viable partial dietary protein source in tilapia feed. Assuming the present market price of feed ingredients in Cameroon, a diet with 13% fishmeal and 30% brewery draff is the most promising. However, longer-term experiments under field conditions and an economical survey on cost-effectiveness in terms of transportation and processing (drying and grinding) of brewery draff are needed.

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