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Evaluation of Sugarcane Bagasse as a Feed Ingredient for the Tilapias *Oreochromis niloticus* and *Tilapia zillii*

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Abstract

Raw and cooked sugarcane bagasse (SB) were evaluated as feed ingredients in diets fed to young *Oreochromis niloticus* and *Tilapia zillii*. SB was incorporated into semipurified, isonitrogenous, isocaloric diets at 0, 20 and 40% levels. Experimental diets were fed to triplicate groups of both species for 6 weeks. The performance of *O. niloticus* and *T. zillii* was significantly reduced at 20 and 40% SB, respectively. Protein and energy digestibilities of *T. zillii* were significantly reduced at 40% SB level. *O. niloticus* showed significantly reduced protein and energy digestibilities at 40 and 20% SB levels, respectively. Cooking of SB seemed to have negligible effects on fish growth or feed digestibility and assimilation. Body composition analyses of both species revealed a decrease in protein contents and an increase in ash contents with increasing dietary SB levels, while both body water and lipids were not significantly affected.

Introduction

Carbohydrates are an important source of dietary energy for herbivorous fishes such as tilapias. The available data suggest that these fishes can efficiently utilize high levels of digestible carbohydrates (Anderson et al. 1984; Teshima et al. 1985; El-Sayed and Garling 1988). In addition, several unconventional carbohydrate sources, namely agricultural by-products, are available at extremely low prices in many regions. However, little attention has been paid to the use of these sources in fish feeds. Instead, conventional energy sources such as wheat, rice and corn by-products are widely used as fish feeds, despite the fact that their production hardly meets the needs of the livestock industry. Therefore, it is imperative that unconventional sources of nonprotein energy be used in fish feeds.

Sugarcane bagasse (SB) is the residue of crushing and milling of sugarcane. It contains a reasonable content of nitrogen-free extract (NFE) (Table 1). Sugar bagasse has been used as a supplemental feed for cattle (Randel et al. 1971). Randel (1970a) reported that up to 30% SB can be added to the feed of male calves without any adverse effect on their performance. Milk production of dairy cattle was not reduced when 22.5% SB was included in their diets (Randel 1970b). However, the use of this by-product as a supplemental energy source for tilapia has not received any attention, despite its availability in many tropical and subtropical regions where tilapia culture is well established.

Table 1. Percentage composition of raw and cooked sugarcane bagasse on dry weight basis.

Ingredients	Constituents (%)					
	Water	Protein	Lipid	Fiber	Ash	NFE[1]
Raw	3.22	1.32	0.40	51.06	2.73	44.49
Cooked	3.06	1.19	0.35	49.52	2.70	46.24

[1] Nitrogen free extract, determined by difference.

This preliminary study was conducted at the Michigan State University aquaculture facility (USA) to evaluate the potential of SB as a supplemental feed ingredient for the tilapias *Oreochromis niloticus* and *Tilapia zillii*.

Materials and Methods

Thirty specimens each of *O. niloticus* and *T. zillii* with an average initial weight of about 10 g were randomly selected and stocked into each of the thirty 110-l culture aquaria. The aquaria were supplied with a flow-through well water at a rate of 1 l/minute. Each aquarium was also equipped with an air stone and a 200-watt heater to keep the water temperature at 25 ± 1°C. The aquaria were illuminated by overhead fluorescent lighting at 14 hours light: 10 hours dark.

Fishes were fed the test diets for 1 week to acclimate them to aquaria feeding. At the end of the acclimation period, fish in each aquarium were recounted and collectively weighed to the nearest g.

SB was incorporated into the diets at 0, 20 and 40% levels on a dry weight basis. SB was finely ground in a blender and dried in a forced air oven for 24 hours. A portion of this product was separated and cooked in boiling water for 30 minutes, then dried for 24 hours. Chemical analysis of raw (RSB) and cooked (CSB) sugarcane bagasse was performed (Table 1) using the standard AOAC (1980) methods. CSB was included into separate experimental diets to test the effect of thermal treatment on feed digestibility and utilization.

Five semipurified, isonitrogenous (30% crude protein), isocaloric (4.5 kcal $GE.g^{-1}$ diets were formulated (Table 2). As SB was increased by 20% intervals, dietary dextrin and α-cell levels were readjusted to maintain dietary energy and to keep the fiber content of all diets constant. Diets were prepared as described by El-Sayed (1990). The gross energies (GE) of the diets were determined using the adiabatic oxygen bomb calorimeter.

Table 2. Percentage composition and proximate analyses of the test diets based on dry weights. R, raw sugarcane bagasse; C, cooked sugarcane bagasse.

Ingredient %	% Sugarcane bagasse in the diets				
	0 (control)	20 R	20 C	40 R	40 C
Casein	23.4	23.2	23.2	23.0	23.0
Gelatin	10.6	10.4	10.3	10.0	10.0
Dextrin	34.0	25.5	25.5	15.0	15.0
Sugarcane bagasse	-	20.0	20.0	40.0	40.0
α-Cell	21.5	10.4	10.5	1.5	1.5
Soybean oil	3.0	3.0	3.0	3.0	3.0
Cod liver oil	2.0	2.0	2.0	2.0	2.0
Mineral mix[1]	4.0	4.0	4.0	4.0	4.0
Vitamin mix[1]	1.0	1.0	1.0	1.0	1.0
Chromic oxide	0.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0
Proximate analyses (%)					
Crude protein	30.11	30.44	30.37	30.72	30.96
Ether extract	5.20	4.94	4.73	5.11	5.06
Ash content	3.94	4.48	4.67	5.21	5.13
Crude fiber	22.96	21.42	22.79	21.64	22.04
NFE[2]	37.79	37.35	37.44	37.33	36.81
GE ($kcal \cdot g^{-1}$)[3]	4.60	4.56	4.63	4.49	4.51

[1] NRC (1977).

[2] Nitrogen free extract (determined by difference).

[3] Gross energy, determined by the adiabatic oxygen bomb calorimeter.

Each diet was fed to triplicate groups of young *O. niloticus* and *T. zillii* at a daily rate of 3% of their live weights divided into two equal feedings (0900 and 1600 hours) for 6 weeks. Fish were weighed weekly and the amount of feed given to each group was readjusted accordingly.

Feces were gently siphoned from culture aquaria, immediately before each feeding, during the last 3 days of the study. Feces from all fish of the same treatment were pooled and dried for 24 hours at 100°C in a drying oven. Apparent protein digestibility (APD) and energy digestibility (AED) were measured by the chromic oxide indicator method as described by Furakawa and Tsukahara (1966).

At the termination of the feeding trial, all fish in each aquarium were removed and weighed collectively. Ten fish were randomly selected from each aquarium, their individual lengths and weights recorded and then frozen at -20°C for final body analysis. Initial body analysis was conducted on 10 fish which were randomly selected from each species before the beginning of the study. Initial and final body analyses were performed using the standard AOAC (1980) methods.

The growth performance results were subjected to a one-way analysis of variance. The differences between means were tested at $P=0.05$ significance level using the orthogonal polynomial procedures as described by Gill (1981).

Results

The specific growth rate (SGR), feed conversion (FC), protein efficiency ratio (PER), protein production value (PPV) and condition factor (K) of *O. niloticus* and *T. zillii* were sharply retarded ($P<0.05$) at 20 and 40% SB levels, respectively (Table 3). Cooking of SB seemed to have negligible effects ($P>0.05$) on growth performance of either species.

Protein digestibility of both species and energy digestibility of *T. zillii* were significantly decreased ($P<0.05$) at 40% SB level, while energy digestibility of *O. niloticus* was significantly decreased ($P<0.05$) at 20% SB level (Table 4). Cooking of SB did not significantly affect ($P>0.05$) protein or energy digestibility in both species.

With the exception of protein and ash contents, body compositions of both species were not significantly affected by dietary treatments (Table 5). Body protein of *O. niloticus* was decreased, while body ash increased ($P<0.05$) at 20% SB level. In case of *T. zillii*, body protein was significantly reduced ($P<0.05$) only at 40% SB inclusion level.

Table 3. The performance of *O. niloticus* and *T. zillii* fingerlings fed the test diets. Figures with different superscripts in the same column for each species are significantly different ($P<0.05$). R, raw sugarcane bagasse; C, cooked sugarcane bagasse.

% SB	Initial* wt (g)	Final wt (g)	SGR[1]	FC[2]	PER[3]	PPV[4]	NER[5]	K[6]
O. niloticus:								
0	10.00	21.00^{b}	1.77^{a}	1.46^{a}	2.27^{a}	37.69^{a}	26.55^{a}	2.48^{a}
20 R	9.00	16.10^{b}	1.37^{b}	1.93^{b}	1.57^{b}	30.68^{b}	19.37^{b}	2.12^{b}
20 C	9.00	16.50^{b}	1.44^{b}	1.82^{b}	1.81^{b}	27.98^{b}	18.17^{b}	2.02^{b}
40 R	8.50	13.00^{c}	1.01^{c}	2.93^{c}	1.13^{c}	14.58^{c}	11.22^{c}	1.84^{c}
40 C	9.50	14.10^{c}	0.94^{c}	2.88^{c}	1.13^{c}	13.58^{c}	10.89^{c}	1.92^{c}
T. zillii:								
0	10.00	20.20^{a}	1.67^{a}	1.37^{a}	2.50^{a}	39.32^{a}	30.23^{a}	2.21^{a}
20 R	11.00	20.00^{a}	1.42^{a}	1.57^{a}	2.26^{a}	37.67^{a}	20.83^{b}	2.02^{a}
20 C	10.00	18.90^{a}	1.51^{a}	1.65^{a}	2.23^{a}	35.90^{a}	22.53^{b}	2.14^{a}
40 R	11.00	16.00^{b}	0.89^{b}	2.54^{b}	1.13^{b}	19.98^{b}	11.92^{c}	1.72^{b}
40 C	10.50	16.10^{b}	1.00^{b}	2.43^{b}	1.13^{b}	18.65^{b}	10.41^{c}	1.76^{b}

*Initial weights were not significantly different ($P>0.05$).

[1] Specific growth rate = 100 ($\log_e$ final wt-$\log_e$ initial wt)/time (days).

[2] Feed conversion = g dry feed given/g live wt gain.

[3] Protein efficiency ratio = g live wt gain/g protein fed.

[4] Protein production value = 100 (protein gain/g protein fed).

[5] Net energy retention = 100 (energy retained (kcal))/energy intake (kcal).

[6] Condition factor = 100 (fish wt (g))/fish length^3 (cm).

Table 4. Apparent protein digestibility (APD) and apparent energy digestibility (AED) of *O. niloticus* and *T. zillii* fed the test diets. Figures with different superscripts in the same column for each species are significantly different ($P<0.05$). R, raw sugarcane bagasse; C, cooked sugarcane bagasse.

Species	% SB	APD	APD as % of control	AED	AED as % of control
O. niloticus	0	96.36^{b}	100.00^{a}	91.40^{a}	100.00^{a}
	20 R	86.20^{a}	89.46^{a}	73.00^{b}	79.86^{b}
	20 C	88.33^{a}	91.67^{a}	75.00^{b}	82.06^{b}
	40 R	72.11^{b}	74.83^{b}	54.30^{b}	59.41^{c}
	40 C	76.00^{b}	78.89^{b}	56.20^{b}	61.48^{c}
T. zillii	0	95.20^{a}	100.00^{a}	92.30^{a}	100.00^{a}
	20 R	90.53^{a}	95.60^{a}	78.20^{a}	84.72^{a}
	20 C	92.22^{a}	96.85^{a}	80.00^{a}	86.68^{a}
	40 R	75.40^{b}	79.20^{b}	63.20^{b}	68.47^{b}
	40 C	80.06^{ba}	84.03^{ba}	64.12^{b}	74.80^{b}

Table 5. Body composition of *O. niloticus* and *T. zillii* fed the test diets. Figures with different superscripts in the same column for each species are significantly different ($P<0.05$). R, raw sugarcane bagasse; C, cooked sugarcane bagasse.

Species	% SB	Body compositions (% dry weight)			
		Water	Protein	Lipid	Ash
O. niloticus	Initial	68.08	54.00	25.00	21.21
	0	70.32^a	57.03^a	25.33^a	18.00^a
	20 R	67.98^a	55.11^a	23.89^a	21.14^b
	20 C	69.20^a	53.00^b	24.76^a	22.03^b
	40 R	67.89^a	49.81^c	24.62^a	24.79^c
	40 C	68.20^a	50.42^c	23.91^a	25.86^c
T. zillii	Initial	70.10	52.41	29.33	18.50
	0	68.39^a	54.61^a	26.22^a	19.00^a
	20 R	69.84^a	52.78^a	25.00^a	23.14^b
	20 C	70.10^a	53.04^a	26.02^a	22.59^b
	40 R	68.70^a	50.10^b	25.13^a	24.78^b
	40 C	70.00^a	50.40^b	24.22^a	24.39^b

Discussion

The present study demonstrated that *T. zillii* can utilize and digest SB more efficiently than does *O. niloticus*. Up to 20% SB can be added to the diets of *T. zillii* without significant adverse effects on their performance, while this inclusion level resulted in a significant reduction in growth and feed utilization efficiency of *O. niloticus*. Despite this sharp reduction in fish performance at this substitution level, fish growth and feed utilization were still good, bearing in mind the reduction in diets cost caused by the incorporation of SB.

The high fiber content of SB may limit its use as an energy source for fish. Studies on rainbow trout (Hilton and Atkenson 1982) and *O. niloticus* (Anderson et al. 1984; Teshima et al. 1987) demonstrated that increasing fiber levels in the diets resulted in a significant reduction in fish growth and feed digestibility and assimilation. However, the reduction in the performance of tilapias fed on SB-based diets in the present study may have not been caused only by the high fiber content of the diets, since all diets (including the control) contained approximately equal amounts of dietary fiber. The reason for this reduction in fish performance is not clear.

The digestibility and utilization of polysaccharides could be improved by cooking. Schmitz et al. (1982) reported a significant increase in corn starch digestibility by European eels when it was hydrothermally treated and gelatinized. Studies on trout (Smith 1976) have also demonstrated that cooked starch was better digested and assimilated than raw starch. However, cooking the bagasse in the present study seemed to have negligible effects on protein and energy digestibility in either *O. niloticus* or *T. zillii.* Other means of chemical, biological and thermal treatments of sugarcane bagasse should be tried in order to improve its nutritional value for fish.

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