As. J. Food Ag-Ind. **2010**, 3(03), 363-370

OPEN ACCESS

Asian Journal of Food and Agro-Industry
ISSN 1906-3040
Available online at www.ajofai.info

Research Article

Increasing fish feed stability using guar gum: case study with *Channa striata*

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This paper was originally presented at the International Conference on the Role of Universities in Hands-On Education, Chiang Mai, Thailand, August 2009.

Abstract

This research aimed to study the effects of the addition of guar gum, an indigestible binder, to processed feed for rainbow trout, on both the growth rate of *Channa striata* and its feces characteristics. Guar gum was added to increase fecal stability or, in another words, to lower the breakdown of feces that causes dispersion of nitrogen, carbon and phosphorus sources into the wastewater. *Channa striata* was selected as the experimental fish with an approximate body length of 4 inches. Guar gum was varied at 0.01, 0.02 and 0.03% of gum to trout feed. Specific growth rates and feed conversion were calculated based on fish weights. Characteristic of feces and organic nitrogen in feed and water were analyzed. Feces stability increased as percentage of guar gum addition increased. The binder-stabilized feces remained larger, denser and easier to collect. The diets containing guar gum had beneficial effect on feed conversion and growth rate. The growth rates of *Channa striata* were 50.0%, 48.4%, 48.4% and 48.3% at 0.0 (control), 0.01, 0.02 and 0.03% of guar gum, respectively.

Keywords: feed additives, rainbow trout, aquaculture, wastewater, feces stability, Thailand.

Introduction

The Royal Project Foundation at Doi Inthanon in the north of Thailand initiated an experimental fishery station to harvest rainbow trout. The farm uses a flow-through system that requires a high amount of water from the nearby Siriphum Waterfall. During the summer months, the farm has to decrease the number of ponds since the water quantity is limited. Thus, the trout stocking density in each pond increased, generating a higher demand for dissolved oxygen (DO) in the water and an increase in ammonia concentration [1]. To solve the problem, the station sometimes retards feeding, resulting in a lower growth rate of the fish. Fig. 1 shows the water inlet from the waterfall at the farm.

Figure 1. A mature rainbow trout at the Royal Project Foundation farm, Doi Inthanon.

Major wastes produced by aquaculture operations are uneaten and/or spilled feed and feces which directly affect water quality, such as ammonia, nitrogen, pH, temperature and dissolved oxygen [2, 3]. In addition, feces are major sources of organic nitrogen and phosphorus that are transformed by microorganisms to toxic compounds such as ammonia, nitrite and nitrate [4].

The addition of guar gum, a high-viscosity, indigestible binder, to the fish feed can slow the breakdown of feces and reduce the dispersion of the aforementioned toxic compounds. Guar gum is neither digestible nor absorbed into the fish, thus it could help prolong usage life of water in the rainbow trout ponds [5].

The objective of this research was to study the effects of adding guar gum to fish feed and to assess various compositions on the fish growth rate and feces characteristics. *Channa striata*, or Striped Snakehead fish were used as a preliminary case study before applying to the trout aquaculture, since it has resemblance in morphology and physiology of digestive tract and feeding behaviour [6].

Materials and Methods

Diet and husbandry

Channa striata was selected as the experimental fish. Each had an approximate body length of 10 cm or 4 inches, as seen in Figure 2. The fish were fed twice daily during a period of 20 days. The daily intake was 0.5% of body weight. The feed was dispensed manually at 9:30 am and 4 pm. The remaining feed was removed half an hour after feeding. This feeding regime resulted in the production of fecal pellets on the verge of excretion at 11:30 pm. The fecal pellets were collected to study the physical and density characteristics. Ammonia, nitrite and nitrate were determined.

Figure 2. Juvenile *Channa striata*.

Four diets were formulated from the basic feed formula containing balanced levels of amino acids, fatty acids, vitamins and minerals. All components exceeded the levels recommended for standards of trout feed. One negative control was without the guar gum binder, while the other three contained the binder in different concentrations (Table 1). The diets were produced by grinding basic diets and mixing with guar gum.

Table 1. Composition of the experimental diets.

Unit		Diet 1	Diet 2	Diet 3	Diet 4
		BD	VG 0.01%	VG 0.02%	VG 0.03%
BD	g kg^{-1}	1000	1000	1000	1000
Guar gum	g kg^{-1}	-	0.1	0.2	0.3

(BD= basic diet, VG= viscosity guar gum)

Channa striata sizes were 4±1 inches. Experiments were conducted in 10 aquarium tanks (height: 35 cm., width: 40 cm., length: 50 cm) with the water volume of 30 litres. The water flow for each tank was adjusted to 12 L/min.

Specific growth rate and feed conversion ratio

For each diet test, three experimental trials were conducted with duplicate groups of *Channa striata.* The effects of the dietary binder treatments on specific growth rate (SGR) and feed conversion ratio (FCR) were investigated. The SGR and FCR were calculated by weighing fish at every 5 days and calculating from the feed intake [7, 8]. Differences of SGR and FCR in each treatment were analyzed using multiple comparison statistics. The fish SGR was calculated as shown in the following equation using the initial and final mean weights.

$$SGR[\%d] = \frac{In(MFW) - In(MIW)}{t(final\ date) - t(initial\ date)} x100 \quad (1)$$

MFW = mean final weight
MIW = mean initial weight

The FCR was calculated as:

$$FCR = \frac{Feed\ [kg]}{Weight\ [kg]} \quad (2)$$

Feces dispersion

Fish feces were collected for image analysis and size measurement. Microscopic method was used to observe physical characteristics of the feces. During the experiment, feces were preserved in aluminium dishes, hermetically sealed with a plastic film to prevent dehydration, and cooled at 4°C [9].

Water quality

Samples for water quality analysis were collected every day. Ammonia, nitrite and nitrate were determined. The differences were determined using the statistical multiple comparison method [10].

Results and Discussion

Specific growth rate and feed conversion ratio

Channa striata were fed for 20 days with the basic diets, diets with guar gum of 0.01%, 0.02% and 0.03%. Table 2 presents the SGR calculated from the experimental results. The specific growth rate (SGR) were affected by guar gum at 0.05 significant level and SGR in treatment with guar gum were not different at 0.05 significant level.

Normally, the specific growth rate of juvenile *Channa striata* were 90-95% with the feed weight of 1-1.5% of fish weight [11]. However, the SGR were 50.0%, 48.4%, 48.4% and 48.3% in basic diet, diet with guar gum 0.01%, 0.02% and 0.03%, respectively. Suitable rate of guar gum in feed should not exceed 0.05% because it may be toxic to the fish [12]. The cause of a lower SGR than the normal rate was the lower feed weight of 0.5% of fish weight. The SGR with diets with guar gum addition was lower than that without guar gum addition, since guar gum is indigestible and may obstruct the absorption of nutrients of the fish especially fat, which is one of the most important nutrients for growth [13, 14].

Table 2. Specific growth rate of *Channa striata* were fed by basic diet, diet with 0.01%, 0.02% and 0.03% of guar gum within 20 days (Mean ± S.D.)

Days	Diet	**Specific growth rate** (Mean ± S.D.)
5	Rainbow trout feed	$46.89^{a} \pm 0.23$
	Rainbow trout feed + 0.01% guar gum	$45.18^{b} \pm 0.14$
	Rainbow trout feed + 0.02% guar gum	$45.04^{b} \pm 0.47$
	Rainbow trout feed + 0.03% guar gum	$45.30^{b} \pm 0.76$
10	Rainbow trout feed	$48.31^{a} \pm 0.28$
	Rainbow trout feed + 0.01% guar gum	$46.58^{b} \pm 0.23$
	Rainbow trout feed + 0.02% guar gum	$46.67^{b} \pm 0.41$
	Rainbow trout feed + 0.03% guar gum	$46.78^{b} \pm 0.25$
15	Rainbow trout feed	$49.20^{a} \pm 0.30$
	Rainbow trout feed + 0.01% guar gum	$47.61^{b} \pm 0.22$
	Rainbow trout feed + 0.02% guar gum	$47.58^{b} \pm 0.30$
	Rainbow trout feed + 0.03% guar gum	$47.48^{b} \pm 0.21$
20	Rainbow trout feed	$49.99^{a} \pm 0.30$
	Rainbow trout feed + 0.01% guar gum	$48.40^{b} \pm 0.19$
	Rainbow trout feed + 0.02% guar gum	$48.37^{b} \pm 0.29$
	Rainbow trout feed + 0.03% guar gum	$48.28^{b} \pm 0.17$

The feed conversion ratio (FCR) was analyzed at 95% confident interval by feeding at 0.5%of fish weight per day. With an addition of guar gum, FCRs were insignificantly different at approximately 0.6 per feeding at 0.5% of fish weight (table 3). Normally, the FCR of *Channa striata* were 1.6 per feeding at 1.2-1.5% of fish weight [15]. During the feeding time between 5-10 days, FCR decreased to 0.2-0.3 due to fish were sick during that period [8].

Table 3. Feed conversion ratio (FCR) of *Channa striata* fed by basic diet, diet with 0.01%, 0.02% and 0.03% of guar gum within 20 days (Mean ± S.D.)

Days	Diet	**Feed conversion ratio** (Mean ± S.D.)
5	Rainbow trout feed	$0.51^{a} \pm 0.10$
	Rainbow trout feed + 0.01% guar gum	$0.54^{a} \pm 0.06$
	Rainbow trout feed + 0.02% guar gum	$0.54^{a} \pm 0.06$
	Rainbow trout feed + 0.03% guar gum	$0.54^{a} \pm 0.13$
10	Rainbow trout feed	$0.24^{a} \pm 0.02$
	Rainbow trout feed + 0.01% guar gum	$0.27^{a} \pm 0.03$
	Rainbow trout feed + 0.02% guar gum	$0.27^{a} \pm 0.08$
	Rainbow trout feed + 0.03% guar gum	$0.27^{a} \pm 0.06$
15	Rainbow trout feed	$0.51^{a} \pm 0.10$
	Rainbow trout feed + 0.01% guar gum	$0.54^{a} \pm 0.06$
	Rainbow trout feed + 0.02% guar gum	$0.54^{a} \pm 0.04$
	Rainbow trout feed + 0.03% guar gum	$0.54^{a} \pm 0.13$
20	Rainbow trout feed	$0.59^{a} \pm 0.08$
	Rainbow trout feed + 0.01% guar gum	$0.64^{a} \pm 0.06$
	Rainbow trout feed + 0.02% guar gum	$0.64^{a} \pm 0.07$
	Rainbow trout feed + 0.03% guar gum	$0.64^{a} \pm 0.07$

Fecal dispersion

In rainbow trout farm systems, suspended particles comprised mainly of fish feces significantly impact the total pollutant load in the system [16]. A proportion of these solids can be removed mechanically by sieves and sedimentation devices to prevent buildup and to disperse ammonia from these wastes [17]. The addition of dietary binders to fish feed may result in the production of large feces particles with an enhanced potential to retain leachable components such as ammonia that will result in prolonging water quality in fish culture [18].

Channa striata fed with rainbow trout diet 0, 0.01, 0.02 and 0.03% guar gum showed a noticeable effect on the physical characteristics of the fish feces.

The characteristics were observed through the dimension of feces. The fish feces had dimensions of 4x3, 1x7, 2x9 and 1.5x13cm for 0, 0.01, 0.02, and 0.03% guar gum addition, respectively. Further, the increase in guar gum addition increased feces density visualized by the microscope (100x). Guar gum as a binder possesses an exceptional structural integrity due to continuous re-entanglement of the polysaccharide network [19]. This structural robustness created effective adhesion of feces material to form large particles and hard compaction [20].

Water quality

Water temperature, dissolved oxygen and pH were measured on a daily basis. The temperature, dissolved oxygen and pH were in the range of 26-27.5°C, 7.5-8.2 and 7-8, respectively. Ammonia, nitrite and nitrate concentrations were measured and statistically analyzed by multiple comparison at 95% confident interval. Fish excrete ammonia directly through gill respiration and, in addition, bacteria break down fish feces and uneaten feed to generate ammonia, nitrite (NO_2^-) and nitrate (NO_3^-) from the nitrification process by nitrifying bacteria [21]. An addition of guar gum at 0.01, 0.02, and 0.03% affected the ammonia, nitrite and nitrate concentrations (Table 4). Ammonia concentration decreased slightly over time. They were different at 0.05 significant levels. The experiment with 0.03% guar gum showed the lowest ammonia concentration. The same trend was seen with nitrite concentrations. In addition, nitrite concentration decreased slightly over time. This may have resulted from the nitrification process wherein *Nitrobacter* subsequently transformed nitrite to nitrate [22, 23]. An addition of 0.03% guar gum yielded the lowest nitrate concentration [24].

Table 4. Ammonia, nitrite and nitrate concentrations (Mean ± S.D.)

Days	Diet	Ammonia concentration (Mean ± S.D.)	Nitrite concentration (Mean ± S.D.)	Nitrate concentration (Mean ± S.D.)
5	Rainbow trout feed	$0.38^{a} \pm 0.0000$	$12.51^{a} \pm 0.36$	$24.46^{a} \pm 0.23$
	Rainbow trout feed + 0.01% guar gum	$0.37^{b} \pm 0.0058$	$11.44^{b} \pm 0.42$	$21.13^{ab} \pm 0.68$
	Rainbow trout feed + 0.02% guar gum	$0.35^{c} \pm 0.0067$	$10.90^{b} \pm 0.11$	$19.78^{b} \pm 0.49$
	Rainbow trout feed + 0.03% guar gum	$0.33^{c} \pm 0.0061$	$11.65^{b} \pm 0.31$	$13.65^{c} \pm 1.17$
10	Rainbow trout feed	$0.14^{a} \pm 0.0035$	$12.18^{a} \pm 0.49$	$21.78^{a} \pm 0.22$
	Rainbow trout feed + 0.01% guar gum	$0.13^{a} \pm 0.0116$	$11.19^{ab} \pm 0.82$	$20.44^{ab} \pm 0.68$
	Rainbow trout feed + 0.02% guar gum	$0.13^{a} \pm 0.0064$	$10.39^{b} \pm 0.15$	$19.12^{b} \pm 0.50$
	Rainbow trout feed + 0.03% guar gum	$0.12^{a} \pm 0.0157$	$10.73^{b} \pm 0.03$	$12.96^{c} \pm 1.17$
15	Rainbow trout feed	$0.11^{a} \pm 0.0020$	$10.50^{a} \pm 0.10$	$19.41^{a} \pm 0.22$
	Rainbow trout feed + 0.01% guar gum	$0.07^{b} \pm 0.0007$	$9.37^{b} \pm 0.41$	$18.12^{ab} \pm 0.69$
	Rainbow trout feed + 0.02% guar gum	$0.06^{c} \pm 0.0035$	$8.05^{c} \pm 0.29$	$16.75^{b} \pm 0.48$
	Rainbow trout feed + 0.03% guar gum	$0.05^{d} \pm 0.0000$	$7.40^{c} \pm 0.40$	$10.64^{c} \pm 1.16$
20	Rainbow trout feed	$0.09^{a} \pm 0.0020$	$9.89^{a} \pm 0.27$	$14.72^{a} \pm 0.45$
	Rainbow trout feed + 0.01% guar gum	$0.05^{b} \pm 0.0012$	$8.87^{ab} \pm 0.60$	$13.52^{ab} \pm 0.17$
	Rainbow trout feed + 0.02% guar gum	$0.04^{c} \pm 0.0031$	$7.49^{b} \pm 0.46$	$12.26^{b} \pm 0.72$
	Rainbow trout feed + 0.03% guar gum	$0.02^{d} \pm 0.0042$	$5.67^{c} \pm 0.76$	$5.93^{c} \pm 1.16$

Conclusion

Experiments were conducted to test the effects of guar gum addition to rainbow trout diets using *Channa striata* as a case study. The results showed that guar gum addition lowered the FCRs with the added benefit of heightening feed stability, resulting in lower concentrations of ammonia, nitrite and nitrate in water.

Acknowledgements

The authors would like to express their appreciation for the financial support for this research project from King Mongkut's University of Technology Thonburi.

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