Aquacultural Engineering 57 (2013) 9–17

Contents lists available at ScienceDirect

Aquacultural Engineering

journal homepage: www.elsevier.com/locate/aqua-online

Performance of single-drain and dual-drain tanks in terms of water velocity profile and solids flushing for *in vivo* digestibility studies in juvenile shrimp

Rodrigo A.P.L.F. Carvalho[a,*], Daniel E.L. Lemos[a], Albert G.J. Tacon[b,c]

[a] LAM – Laboratório de Aquicultura, Instituto Oceanográfico, Universidade de São Paulo, P.O. Box 66149, São Paulo, Brazil
[b] Instituto de Investigaciones Oceanológicas, Universidad Autonoma de Baja California, Ensenada, Mexico
[c] Aquatic Farms Ltd., Hawaii, USA

ARTICLE INFO

Article history:
Received 19 September 2012
Accepted 24 May 2013

Keywords:
Dual-drain
Shrimp
Digestibility
Tank design
Water velocity
Solids removal

ABSTRACT

In vivo digestibility determination in shrimp is a challenge because these animals are coprophagous, benthic and slow feeders and the small amount of feces that they produce is difficult to collect. The objective of this study was to evaluate an efficient tank design for the purpose of studying shrimp digestibility. Different tank designs were evaluated considering drain system (dual-drain and single-drain), water inlet flow rate (8, 12, and 16 L min^{-1}) and bottom drain diameter (6, 13, 19, 25 and 50 mm) and their effects on tank hydraulics, water velocity and solids flushing. A circular and slightly conical 500 L tank was adapted with a clarifier for the two dual-drain designs (Cornell-type and central-type) and settling columns for the two single-drain designs (Guelph-F and Guelph-L). Results showed that: (1) water rotational velocity profile was more homogeneous in tanks with larger bottom drain outlets, and water velocity increased with water inlet flow rate from almost zero up to 14.5 ± 0.7 cm s^{-1}; (2) solids flushing, measured as the percentage of feed pellets retained at both the bottom drain and in the settling devices, was positively correlated with the surface loading rate (L min^{-1} flow per m^2) and was more effective at the Guelph-L design fitted with a 150 mm diameter settling column. In this system 100% of the solids were removed at the inflow rate of 16 L min^{-1}. It can be concluded that among the systems evaluated, the Guelph-L at an inflow-rate of 12 L min^{-1} was most efficient for both solids removal and water velocity profile and thus seemed more suitable for shrimp digestibility studies in high performance conditions. Technologies involving hydrodynamic must be intensively applied to solids removal for aquatic species production as well as research purposes like digestibility, which is highlighted in this study.

1. Introduction

Digestibility measurements are a key component when evaluating quality of feed ingredients for nutrition studies. Typically, indirect methods employing dietary markers are used for digestibility measurements in shrimp when maintained in tanks of varying dimensions and shapes. Their feces are collected either by siphoning or by sedimentation within a water column (Cho and Slinger, 1979; Forster et al., 2003; Smith and Tabrett, 2004).

The reported tank volumes for shrimp apparent digestibility studies varied from 20 to 500 L. These are usually rectangular or cylindrical with a flat or slightly conical bottom (Smith et al., 2007; Glencross et al., 2002; Cruz-Suárez et al., 2007; Forster et al., 2003). The large variety of systems and procedures makes it difficult to compare the results and their efficiency in terms of solids or feces removal. Moreover, the diversity of experimental conditions, including feed manufacture and rearing conditions and procedures, creates concerns about the variability of data. Some authors have emphasized the importance of stable environment to minimize shrimp stress as well as optimize nutrients so as to attain maximum growth of experimental animals (Tacon, 1996; D'Abramo and Castell, 1997; Smith and Tabrett, 2004; Glencross et al., 2007).

Compared to most fish species, *in vivo* digestibility determination in shrimp is more challenging because of their benthic behavior which makes it difficult to use conical shaped tanks. Being slow feeders and coprophagous, the removal of feed and feces is complicated, resulting in nutrients rapidly leaching from the feed and feces thus altering the marker to nutrient ratio compromising the quality and the sampling efficiency of the shrimp feces. The technique of

* Corresponding author. Current address: Unidade Acadêmica de Ciências Agrárias/Escola Agrícola de Jundiaí, Universidade Federal do Rio Grande do Norte – UFRN, RN 160, Km 03, Macaíba, RN CEP 59280-000, Brazil. Tel.: +55 84 3342 4800; fax: +55 84 3342 4800.
E-mail addresses: rodrigoplfc@gmail.com, rodrigoplfc@ufrnet.br (R.A.P.L.F. Carvalho).

0144-8609/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.aquaeng.2013.05.004

collecting feces by siphoning, aside from being labor intensive may be criticized for potential undesirable effects upon animal welfare, and as such non-compatible to practical rearing conditions (Tacon, 1996; D'Abramo and Castell, 1997).

There are few studies regarding the design of tanks for aquatic animal rearing. Most of the ones for shrimp have been focused on production (Freeman and Duerr, 1991; Tseng et al., 1998) except for the study of Kumaraguru vasagam et al. (2009) which evaluated a self-cleaning mechanism in a microcosm tank.

In the aquaculture engineering field, numerous studies have focused on solids removal within culture systems. This is important because the fecal matter, uneaten feed, and feed fines can be broken rapidly into much finer particles due to water turbulence, animal motion, scouring, and pumping making it much more difficult to remove fine particulate matter than larger particles (Summerfelt et al., 2000).

The use of clarifiers and swirl separators (also known as Hydrodynamic Vortex Separators – HDVS) is an efficient method for solids removal within fish tanks. Swirl separators have already been used for different applications such as urban drainage systems, water quality control, mineral industry and wastewater treatment (Andoh and Saul, 2003; Vinci et al., 2004; Veerapen et al., 2005).

The tank hydraulics impact directly on the water circulation profile, which in turn increases the solids discharge through the mass displacement from the periphery to the center of the tank and then to the settling device. Knowledge of the factors behind the tank hydraulics, as explored in the studies conducted by Davidson and Summerfelt (2004) and Labatut et al. (2007) together with different solids removal technologies provided an important insight on the application of new concepts into the aquaculture nutrition studies reducing the gap between the laboratory and the practical conditions. This is important if these data are to be applied to practical farm conditions (Tacon, 1996).

The objective of this study was to develop a system to study *in vivo* shrimp digestibility which would combine efficient solids removal, reduced stress and optimize shrimp performance. This study evaluated the effect of system design (dual-drain *versus* single-drain), inflow rate, and secondary drain diameter on the tank hydraulics, water velocity profile and solids flushing efficiency (corresponding to the feed removal efficiency).

2. Materials and methods

2.1. System design and hydraulics

Hydraulics, water velocity profile and solids flushing were evaluated using two settling tank designs and modifications: (1) dual-drain tanks (Cornell-type dual-drain and central-type dual-drain); (2) single-drain tanks (Guelph settling tank design adapted by Forster et al. (2003) – Guelph-F, and the Guelph tank settling design adapted by Lee (2002) – Guelph-L) (Fig. 1).

Three inflow rates (8, 12 and 16 L min^{-1}) and three secondary drain diameters were adopted using polyethylene hose with diameters of 6.0, 12.7 and 19.1 mm for the dual-drain tanks. PVC pipe diameters were 25 and 50 mm for the Guelph-F and 50 mm for the Guelph-L. A total of 27 treatments were run in triplicate.

A single 500 L circular and slightly conical tank made of reinforced fiberglass was modified to evaluate all designs and modifications. The tank frustum measured 1000 and 960 mm (superior and inferior diameters) and 670 mm height. The bottom sloped 5° toward the drain that measured 170 mm × 50 mm × 65 mm (upper and lower diameter plus height, respectively). The bottom drain assembly was the same for all tanks. The internal surface finish was a gel coat application and smooth polishing (Figs. 1 and 2).

The depth of the water in the tanks was 400 mm giving a volume of 0.4 m^3 (tank diameter to water depth ratio of 2.5). The Cornell-type tank was provided with two drains. A primary drain consisting of a 60 mm PVC pipe laminated to the side-wall at 450 mm from the tank bottom. A secondary drain consisting of a 15 mm PVC pipe was laminated in the bottom drain area tangentially to the bottom drain wall. This secondary drain was at a 2° downward angle oriented counter-clockwise (Fig. 1).

The bottom drain of the Cornell-type tank was covered with a 170 mm diameter plate in order to simulate an access barrier of the shrimp into the drain. It was fixed to a 50 mm diameter pipe by an

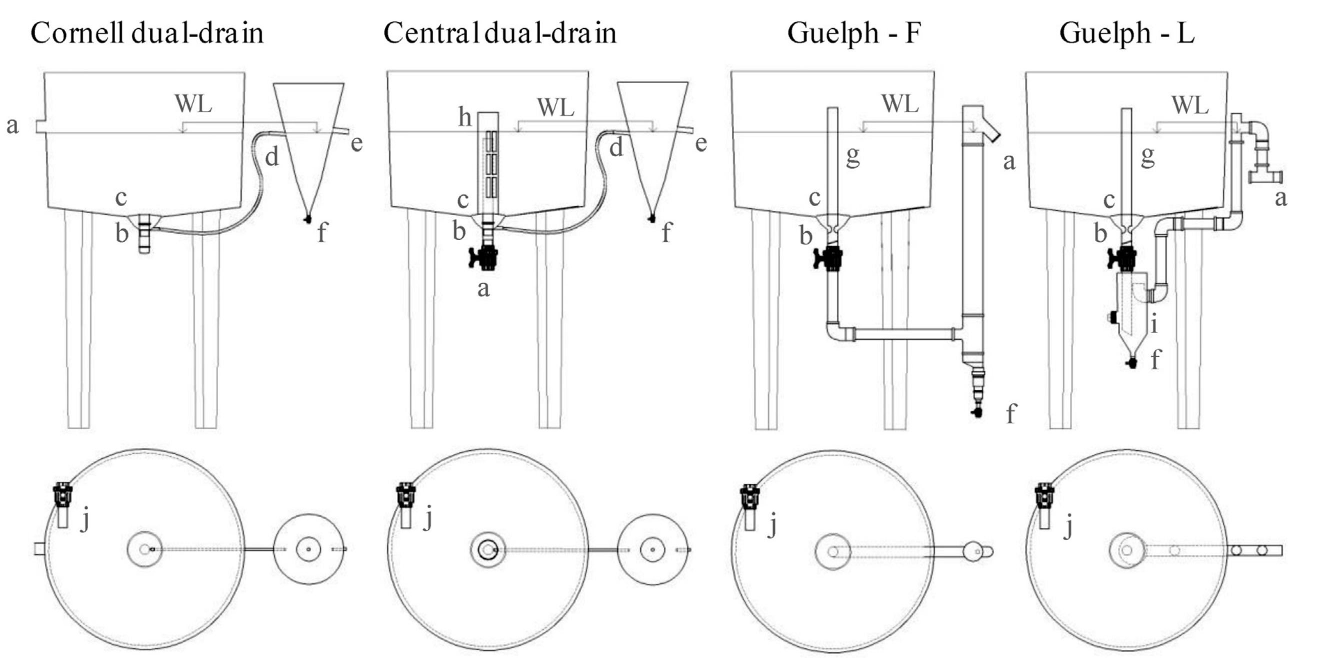

Fig. 1. Plan and section view of the Cornell dual-drain, central dual-drain, Guelph-F and Guelph-L tanks inlet and drains evaluated for digestibility studies with shrimp juveniles. (a) Primary drain (or single drain), (b) secondary drain, (c) cover plate, (d) clarifier inlet, (e) clarifier outlet, (f) outlet for sampling and solids removal, (g) stand pipe (loose pipe), (h) outer screen, (i) settling column, (j) water inlet. WL – water level.