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THE EFFECT OF STOCKING DENSITY ON GROWTH RATE, SURVIVAL AND YIELD OF GIFT TILAPIA (*Oreochromis niloticus)* IN CUBA: CASE STUDY FISH FARM LA JUVENTUD

Lesvia Calderon Herrera
Fishing, Aquaculture Company PESCARIO,
Fish Farm La Juventud,
C No.55 e/ C y C1.Rpto. Hermanos Cruz
lesvia247@gmail.com

Supervisor:

Prof. Helgi Thorarensen
Holar University College
helgi@holar.is

ABSTRACT

An experiment was conducted to examine the effects of stocking density on growth performance and production of male GIFT tilapia (*Oreochromis niloticus*) in the La Juventud fish farm in Cuba. In the study three different densities D1, D2 and D3 (3, 3.2 and 3.5 fish /m² respectively) were tested three each with three replications in nine 2 hectare earthen ponds. The oxygen concentration, temperature and pH in the ponds were measured biweekly. The mean final weight was not significantly different for the D1 (386g) and D2 (389g), but the lower growth corresponded at high density D3. The net production was significantly higher at the D2 density (23390±1703 kg/ ha) than at either D1 (21104±434kg/ha) or D3 (20299±868 kg/ha) density. There was no significant difference in survival rate at different densities. The FCR was highest at the D3 (1.9±0.15) and D2 (1.7±0.02) stocking densities and significantly higher than at the D1 density (1.5±0.13). Stocking density significantly affected water quality, with significantly higher dissolved oxygen and pH at the D1 and D2 than the D3 density. Simple modeling of production costs suggested that the highest gross revenue and net profit contribution were attained at the medium density.

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1. INTRODUCTION

Hunger and malnutrition are the great scourges of humanity. At present, 30% of people in the poorest countries suffer from hunger and this problem is aggravated by population growth and uneven distribution of recourses between countries. The growth of aquaculture in developing countries, can increase food production, make better use of natural resources and contribute to poverty alleviation. (ODELPESCA, 2009). Cuba, a developing country, tries to provide healthy food to the population and increase the per capita fish consumption. Aquaculture is growing in Cuba and it is seen as an important contribution to ensure food security.

Tilapia is one of the most important species in a global aquaculture and is the third largest in volume only after carp and catfish. (FAO, 2014). World production of tilapia is growing rapidly. Tilapia are well suited for aquaculture. They can tolerate high density, their growth is better than other species in intensive farming systems, the flesh is of excellent quality and has good market acceptance (Toledo-Perez & Garcia Capote, 1998).

1.1 Global tilapia production

Global tilapia production exceeded more than 4.5 million metric tons in 2012 (Figure 1) and is forecasted to reach 7.3 million mt. in 2030. (The World Bank, 2013) .

The Asian region dominates the production of tilapia, with China as the largest producer, succeeded by the Philippines, Thailand, Indonesia, Vietnam and Myanmar. Together these countries produced about 3 000 000 mt. of farmed tilapia. (FAO, 2014).

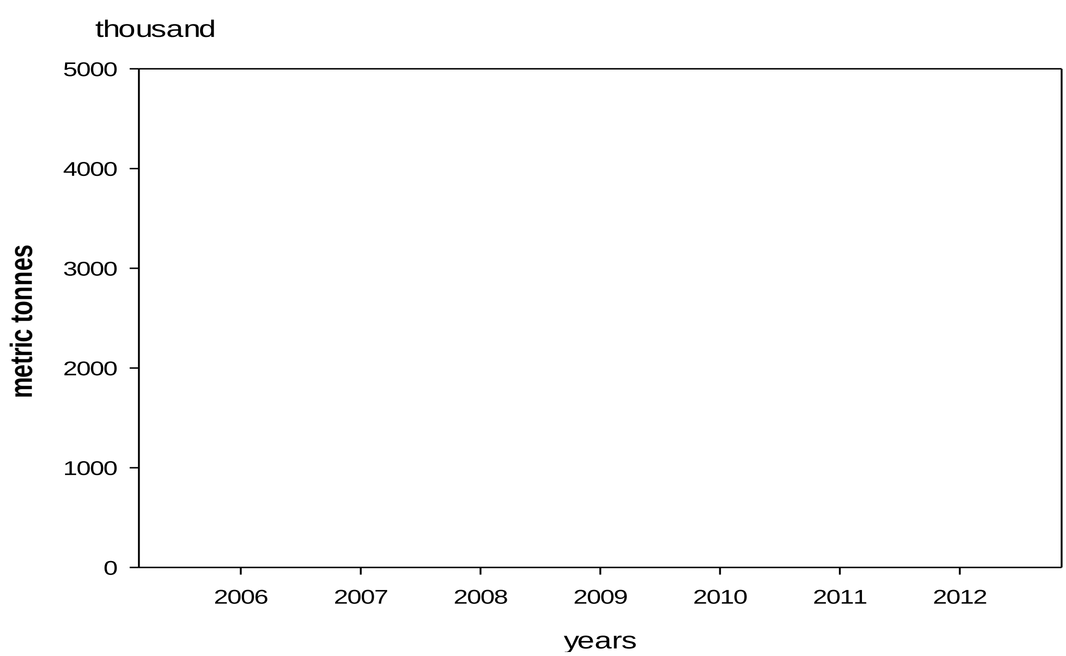

Figure 1: Global Tilapia production 2006-2012. Source: FAO Yearbook, 2012.

Conditions for growing tilapia are good in Latin America. Brazil has abundant resources of water and land. The Brazilian government has passed legislation that encourages the cultivation in cages located in reservoirs. The production in 2010 was close to 200,000 mt of Nile tilapia (Brasil, 2014). Mexico, another large producer of tilapia, produced about 76,000 in 2011 mt. Colombia, Ecuador, Costa Rica and Cuba also contribute to tilapia production in the area.

1.2 Aquaculture in Cuba.

Aquaculture in Cuba is performed by state companies. The government controls the production through the ministry of the food industry and fishing. The fisheries division GEIA has 15 provincial companies. These companies are responsible for the implementation of the aquaculture development plan in every territory. Permanent access to the seed is guaranteed by the provincial companies that operate the fingerling stations, with a production capacity of 50 million juveniles per year.

The government plan for aquaculture emphasizes the sustainable exploitation of resources. Moreover, the objectives of aquaculture plan in Cuba are:

- Provide the domestic market the adequate supply of fish.
- To adopt procedures and standards in aquaculture that ensure the quality and safety of products.
- To promote research and development for the cultivation of exotic species in Cuba, with the aim of increasing production. However, increased production efficiency should not have excessive environmental impact.

Freshwater aquaculture in Cuba uses more than 1400 hectares of ponds for extensive system, where Cyprinids and tilapia are cultured using the natural food available such as phytoplankton and zooplankton. Intensive farming is practiced in about 130, 000 hectares of ponds and cages located in reservoir. In ponds and cages, the fish are fed with commercial feeds to facilitate increased production.

In 2010, Cuban aquaculture produced (Table 1) around 31,000 mt of aquatic organisms, of which 85% originated from freshwater, 10 % from brackish water and 5 % from marine culture (OLDEPESCA, 2012).

Table 1: Aquaculture production in Cuba 2010.

Environment	Production(mt)	Main species
Freshwater	26 350	Silver carp
Brackish water	3 100	Shrimp
Marine	1 550	Mangrove oyster
Total	31000	

1.2.1 Tilapia production in Cuba.

In Cuba, the average temperature is between 26 and 27C°, with maximum between 36°C and 38°C. This is a favorable climate and with a large volume of freshwater provides suitable conditions for tilapia culture. The species *Oreochromis niloticus, Oreochromis aureus* and *Oreochromis mossambicus* were introduce in Cuba from 1980-1999. All these species have aquaculture potential, but the Nile Tilapia *O. niloticus* is the most common in tilapia farming in the country.
In 2004, the World Fish Center obtained GIFT (Genetically –improved tilapia farming) Nile tilapia strain, a strain selected for improved growth and production characteristics. In 2007, a breeding program was started in Cuba with 12 groups of Tilapia nilotica GIFT from Brazil, Thailand and Vietnam. The breeding program was located in the Cuban Aquaculture Research Center (EDTA). The primary breeding objectives were large size, high yield and more efficiency food utilization in intensive systems (Damas, 2012). Presently fish of the GIFT strain are reared in ponds and net cages around the country.

The EDTA provides broodstock for fingerling stations that then produce juveniles for different fish farms. The larvae are produced in cement ponds. The juveniles are then cultured for 45 days in earthen ponds until they reach 10 grams, after that they are transferred to on-growing ponds or cage locate in dams for intensive culture. The introduction of the GIFT strain has greatly increased tilapia production in Cuba. From 2009-2014, tilapia production increased from 800 mt up to 2300 mt (Figure 2) in Cuba. In 2014, half of the tilapia were produced in extensive systems while the rest was produced in net cages and ponds (GEIA, 2015).

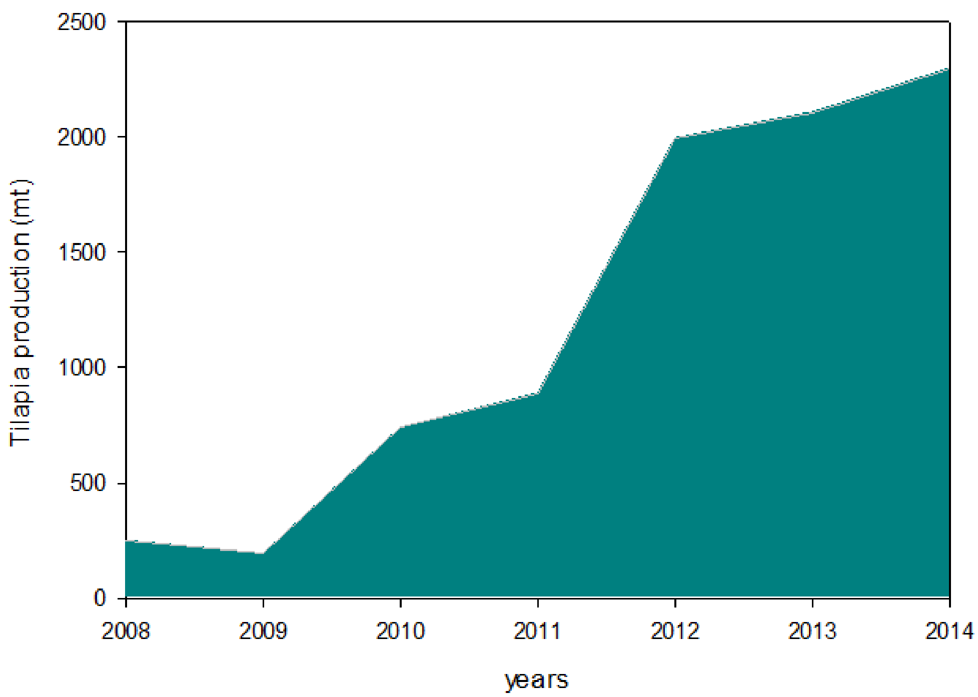

Figure 2: Tilapia Production in Cuba. Source GEIA Statistic (2008-2015).

1.2.2 Aquaculture in Pinar Del Rio and challenges in production.

Early maturation causes stunts in the growth of female tilapia since the females do not feed while they are incubating the eggs. Hence, in mixed populations there is great disparity in the sizes of harvested fish. The presence of female tilapia in ponds causes uncontrolled reproduction, excessive amount of fingerlings and retarded growth of the entire fish population with poor feed conversion rate (Kubitza, 2013). However, this problem can be avoided in all male populations. It is possible to creating all male populations by exposing the fish to 17α metyltestosterone MT at first feeding. In 2011 the production of all male tilapia was introduced at the La Juventud fish farm advised by Research Institute for aquaculture in Vietnam (RIA 1). This has increased fish production in the La juventud fish farm (Figure 3).

The operational procedures for producing tilapia in Cuba (POW) in intensive systems, were issued by the fisheries ministry in 2007. The POW include directions about technical procedures in aquaculture. However, the implementation is the responsibility of the farmer, who can make necessary adjustments according to conditions at different farm (Elizalde & Gonzalo, 2006).

Commonly in tilapia farming, the grow-out is divided in two phases. During the first grow-out phase high stocking rate is used. This phase ends when the fish are 50-80 grams. Then the fish are stocked at lower rates for continued growth at the second phase in other ponds. This management strategy allows better use of pond area and higher yields.

The POW, suggest that the stocking density should be 2.7 fish / m² during the second growing phase. However, monosex GIFT tilapia are often stocked at higher densities with 3- 6 fish/m², (Nguyen, 2005). This is possible because mono-sex culture permits higher stocking rates space for maximum fish production through intensive culture can improve the profitability of the fish farm, so is important to find the ideal stocking density to maximize the productive capacity of the pond (Gibtan *et al.*, 2008; Guerrero & Guerrero, 1988).

In Vietnam male tilapia is stocked in grow out ponds at 4 to 6 fish /m². After six months the fish gained 500g.Good quality food is used and the farmer applied the water exchange in ponds with aeration. (Nguyen, 2005) .

Information about the growth performance of male GIFT tilapia at different rearing densities under conditions such as exist in Cuba are scarce.

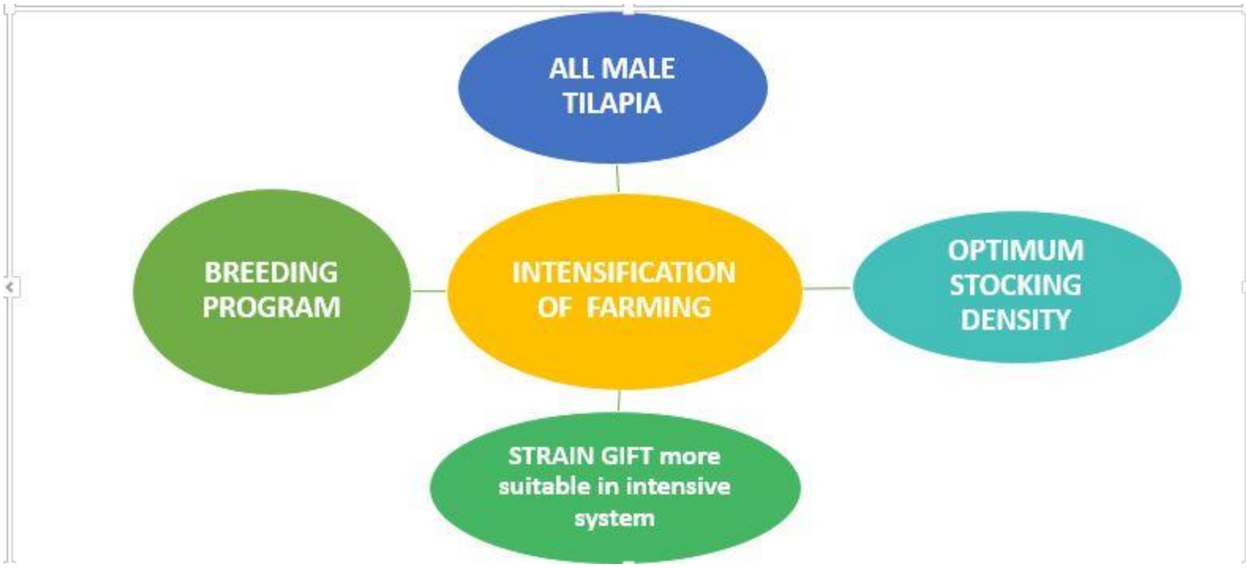

Figure 3: Actions for enhancing Tilapia culture in Fish Farm La Juventud.

2 OBJECTIVES

Information about the growth performance of male GIFT tilapia at different rearing densities under in Cuba are scarce.

Therefore, the main objective of this study was to examine the effects of stocking density on tilapia production parameters. Furthermore, the study attempted to identify which factors determine the relationship between stocking density and production. Specific objectives were to:

- Determine the optimal stocking density of tilapia in ponds for La juventud fish farm.
- Assess the effect of stocking density on oxygen levels and pH in the rearing.
- Make recommendations to the GEIA about changes in the POW regarding stocking density in tilapia aquaculture.

3 LITERATURE REVIEW

3.1 Stocking Density

The stocking density of fish ponds describes the number of fish that are stocked initially per unit area. It is one of the most important factors in determining the production of a fish farm (El-Sayed, 2006). At low levels, increased the stocking density will increase yield. However, stocking density influences survival, growth, behavior, health, water quality, feeding and production. (Figure 4). Therefore, at high levels, increased stocking density can reduce yield. Increased stocking density can increase competition among fish for space and access to feed and thus reduce growth (Quiros, 1999). Furthermore, increased stocking density can compromise water quality in fish ponds which also can compromise growth. The optimum stocking density is the level where the maximum yields is reached (Figure 4).

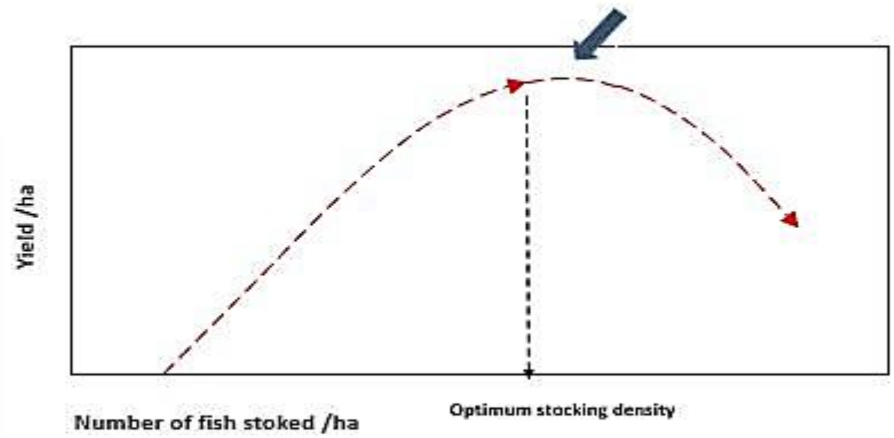

Figure 4: Relation between Stocking density and yield.

The choice of stocking densities of fish depends in part on economic factors and market demands. Increased stocking density may reduce the mean size of fish (Table 2). Therefore, a farmer may choose to stock at suboptimal densities for yield to produce large enough fish. The stocking density is an important indicator that determined the economic viability of the production system. (Aksungu & Aksungur, 2007).

Differences in environmental conditions and rearing unit management such as, feed quality, culture system, species and sex, can affect the optimal stocking density for ponds (Pompa & Green, 1990) (Figure 5). For example, different strains of Nile Tilapia such as Chitralada, GIFT, GET-EXCEL, FaST GenoMar and Supreme, show different growth performance, yield, mortality and resistance for environmental changes. (Ponzonia *et al.*, 2008; Dos Santos *et al.*, 2007).

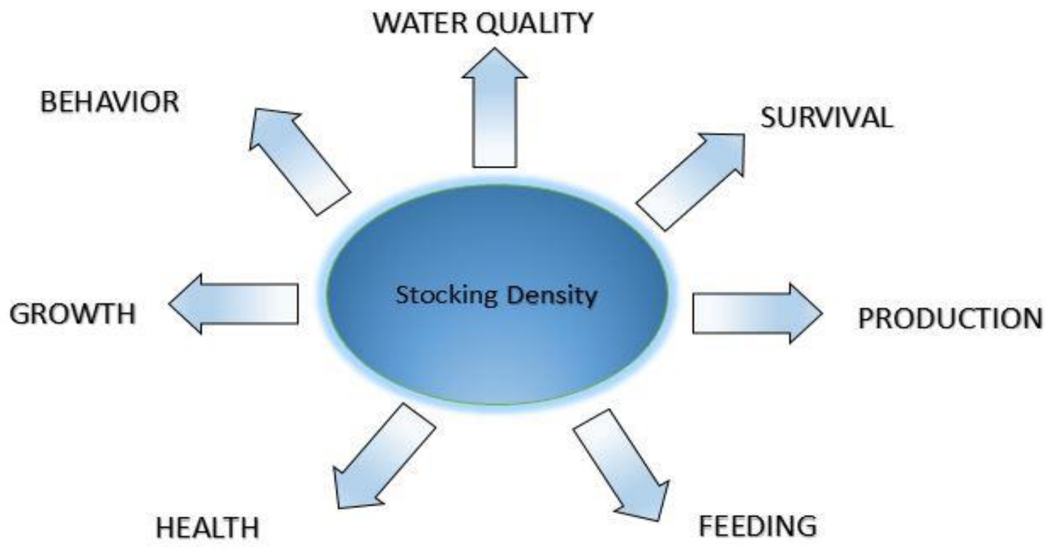

Figure 5: Influence of stocking density on the cultivation.

A number of studies have addressed the effects of stocking density on tilapia production and the main results of 13 studies are summarized in Table 2. Most studies show reduced final weight, when stocking density increase, only three relate maximum growth for the intermediate density. All studies agree, that survival is reduced by increasing the stocking density. The yield is high at the higher stocking density in 10 references and only in three the intermediate density had the higher yield. Into 5 review the FCR is reduced by increasing the density and 7 found the inverse. Just 5 researchers found water quality deterioration at higher density.

Table 2: Summarized results of studies on the effect of stocking density of male tilapia in some system.

References	Densities(fish/m²)	Mean Final weight	Survival	FCR	Yield	Water Quality
Kapinga *et al.*, 2014	3, 13	↓	↓	↓	↑	↓ DO and pH↓
Chakraborty & Banerjee, 2010	0.5 ,1, 1.5 ,2, 2.5 ,3	↑↓	↓		↑↓	↔
Ribeiro & Garcia , 2009	2, 4, 6, 8	↓	↓	↑	↑	
Ronald *et al.*, 2014	1000, 1330, 2000, 2670, 4000 and 5330 fry/m³	↓	↓	↑	↓	
Gullian-Klanian & Arámburu-Adame, 2013	400, 500, 600 fish/m³	↓	↓	↓	↓	↓DO ↓NH3
Chakraborty & Banerjee, 2012	1, 5, 10, 15, 25, 50, 75, 100fish/m³	↑↓	↓	↓	↓	↔
Daudpota & Kalhoro, 2014	200, 250. 300 fish/hapa	↓	↓	↑	↓	↔
Diana *et al.*, 1994	3,6,9 fish/ m³	↑↓	↓	↓	↑↓	↓ DO
Garcia, 2009	2. 4. 6. 8 fish/ m³	↓	↓	↑	↑	↓ DO
De Castro Oliveira, 2010	90, 120, 150 fish/m³	↓	↓	↓	↑	↔
Osofero & Otubusin , 2009	50, 100, 150, 200 fish/m³	↓	↓	↑	↑	
Ammar, 2009	1.2, 1.6 , 2.1 fish/m²	↓	↓	↑	↑↓	↔
Garcia *et al.*, 2013	133, 333, 416, 500 fish/m³,	↓	↓	↑	↑	↓DO,↑NH3 and ↑NO2

(↓) Negative relation the value decrease as density increase. (↑↓) result at intermedia density. (↑) Positive relation the value increase as density increase. (↔) no influence of stocking density in water quality. The arrows indicate changes in water quality.

3.2 Water Quality

Water quality is an important factor in aquaculture and can affect the production. With increased fish density water quality is often compromised.

3.2.1 Dissolved Oxygen Concentration

Low concentrations of dissolved oxygen (DO) in water can compromise growth, cause stress, increase disease susceptibility, reduce appetite and increase mortality in fish. (Bhujel, 2013). From fish such as feces and uneaten feed promote a bacteria and phytoplankton growth. During the day the algae produce high oxygen concentration through photosynthesis, but high amounts of oxygen are consumed in the night for algae, fish and microorganism in the ponds, causing anoxic and poor water quality (Chang & Ouyang, 1988).

It is possible to increase the DO levels by aerating the ponds. Studies on Nile tilapia suggest that it grows better when aerators are used to maintain adequate DO levels compared with fish reared in un-aerated ponds (Macintosh and Little, 1995). When stocking density increases, it is of primary importance to have a secure water supply for to maintain good water quality. Low dissolved oxygen concentration in ponds can improved by a combination of aeration and increased water exchange. (Green *et al.*, 1993)

Moreover, water exchange is important for removing from ponds suspended solids, toxic metabolic wastes from fish (Chorm & Webster, 2006). Studies have indicated that fish growth is highest when water is continuously exchanged in ponds. (Aquaculture SA, 2003)

3.2.2 pH

The pH in fish ponds fluctuates depending on the CO2 levels in water. Fish and other organism excrete CO_2 as product of metabolism. During the day, algae and plants remove CO_2 from water through photosynthesis and then the pH rises. At night when the photosynthesis stops the CO_2 levels increase again and pH is reduced. This cycle is repeated every 24 hours. Fluctuations in CO2 concentration and pH tends to increase with increasing biomass of fish (Tucker & D'Abramo, 2008).

3.2.3 Ammonia

Too high ammonia levels can cause stress and damages to gills and other tissues**.** Fish exposed to low levels of ammonia over time are more susceptible to bacterial infections, have poor growth, and will not tolerate routine handling. At high density the concentration of ammonia is increased (Floyd & Watson, 2012).

3.3 Health of tilapia

High density may cause stress in fish which in turn may suppress immune function in fish and make them more vulnerable to disease. Fin damage is another result of too high density. For example, streptococci in tilapia first appeared in Cuba in cage farming where fish density is high. (Silveira, 2010).

3.4 Behavior

High stocking density will increase social interactions among fish, and dominance hierarchies may be formed (Barcellos & Nikolaieswky, 1999). Dominant individuals may restrict the access of subordinate individuals to resources such as food and territory. At optimum stocking density, aggressiveness is reduced and instead energy can be channel to growth. (Schwedler & Johson, 2000).

3.5 Survival

The cannibalism is more common in larvae and juveniles of tilapia. This phenomenon is associated with large size variation, high population densities and limited food availability. Heterogeneous sizes, lead often social dominance, resulting in cannibalism. So stock tilapia with uniform sizes into the pond, may avoid this problem. (Smith & Reay, 1991). Also poor handling, stress and severe competition for food and space resulted in lower survival rates (Aurbun University, 2003).

4 MATERIAL AND METHODS.

4.1 Experiment design

The experiment was performed in La Juventud fish farm, in the municipality of Los Palacios, Pinar del Rio province in Cuba (Figure 6). Nine 2 hectare ponds with 1.2 average depth were used in the study. Before the experiment began, the ponds were dried and quicklime (1mt/ha) was applied to eliminate parasites, bacteria and other unwanted organisms. Inorganic fertilizers (120 kg/ ha of ammonium nitrate and 22 kg/ha triple superphosphate), were applied to the ponds while the fish were small (10-50g) to promote plankton growth

Figure 6: Fish Farm La Juventud.

Male GIFT Juveniles (mean weight: 10 g) were stocked at densities of 3.0, 3.2 and 3.5 fish /m² (Table 3). Each density level was applied in triplicate ponds. The duration of the experiment was 8 months. Water exchange in the ponds was continuous maintained at 15% and increased if water quality was compromised. No aerator was used**.**

Table 3: Stocking density per treatment.

Treatment	Fish//m²	Fish/ponds
D1	3	60000
D2	3.2	65000
D3	3.5	70000

4.2 Feed

The fish were fed with non-floating dry feed twice each day, at 8 am and 3 pm according to POW directions for intensive farming of tilapia in ponds. The feed was produced following the Toledo formulation (Toledo-Perez, 2005) (Table 4) at the ALISUR and Tropical Feed processing plants. The feed did not contain any fish meal during grow out phase.

Table 4: Composition of foodstuff for tilapia in Cuba.

Ingredients	*Inclusion (%)*
Defatted soy flour	50
Wheat bran	33
Whole wheat grinding	10
Soybean oil	3
Dicalcium phosphate	3
Premix of vitamins and minerals	1
Total	100
Chemical composition of (% dry matter)	
Protein (%)	28.34
Lipids (%)	6.1
Energy (Mj /kg)	9.03

4.3 Samples

Every month fish was sampled using a seine net (mesh A7 (50 meter length, 5 meter height). At least 5% of the fish in each pond were sampled to estimate the mean weight. The feeding rate was adjusted according to the mean weight and the total biomass as prescribed by POW (Table 5).

Table 5: Daily feeding rate as % of biomass.

Weight (g)	% Biomass
10-20	10
21-35	7
36-49	5
50-85	4
86-133	3
134-223	2
224-422	1.4

4.4 Measurement water quality

Every two weeks the temperature and the levels of dissolved oxygen and were measured at 7am using Oxyguard MK III) oxygen meter. At the same time the pH was also measured with a Hanna pH meter. If oxygen levels were low, water exchange was increased.

4.5 Harvest and growth performance

After 240 days, the ponds were harvested. The total biomass of fish was weighed and the final mean weight, daily weight gain, yield and survival rates were calculated. The total amount of feed given in each treatment was also added up at the end of the study to calculate FCR. The following formulas were used to calculate growth performance and feed efficiency:

$FCR = \text{Weight gained by fish (g)} / \text{Weight of feed consumed (g)}$
$ADW = \text{Final weight of fish} - \text{Initial weight of fish} / \text{Days of rearing}$
$\%Survival = \text{No. of fish harvested} / \text{No. of fish stocked x 100}$
$SGR = Ln\ Final\ weight - LnInitial\ weight / \text{Experimental duration x 100}$
$\text{Weight gained} = \text{Final weight} - \text{Initial weigh}$
$Yield = Kgharvested/hectares/1000$

4.6 Simple economy analysis

A production model was developed to assess the production cost and revenue for the three densities used in the experiment. Besides was included the depreciation of equipment used in the cultivation, harvesting costs and labor and sales prices of juvenile and whole tilapia. The net contribution from each stocking density was obtained by subtracting the total cost of production (cost of fingerlings, food and other cost) by total sales. Thus, it was possible to determine the net contribution per 1 kg of fish, dividing the net contribution between the final biomass obtained in each stocking density.

4.7 Data analysis

The data were analyzed with a one-way analysis of variance (ANOVA) using Sigmaplot 2013.The normality of the data was confirmed with Shapiro –Wilk test and pairwise comparison among means was performed with the Holm-Sidak method with accepting significant difference at $p<0.05$ The Friedman repeated measured analysis of variance was used to compare oxygen, pH and temperature levels.

5 RESULTS

5.1 Growth and survival

The growth in the D1 and D2 groups was better that in group D3 (Figure 7). Similarly, the mean final weight, specific growth rate (SGR) and average daily weight gain (DWG) were all significantly higher in D2 and D1than D3 (Table 6). There was no significant difference in any of these variables between D1 and D2.

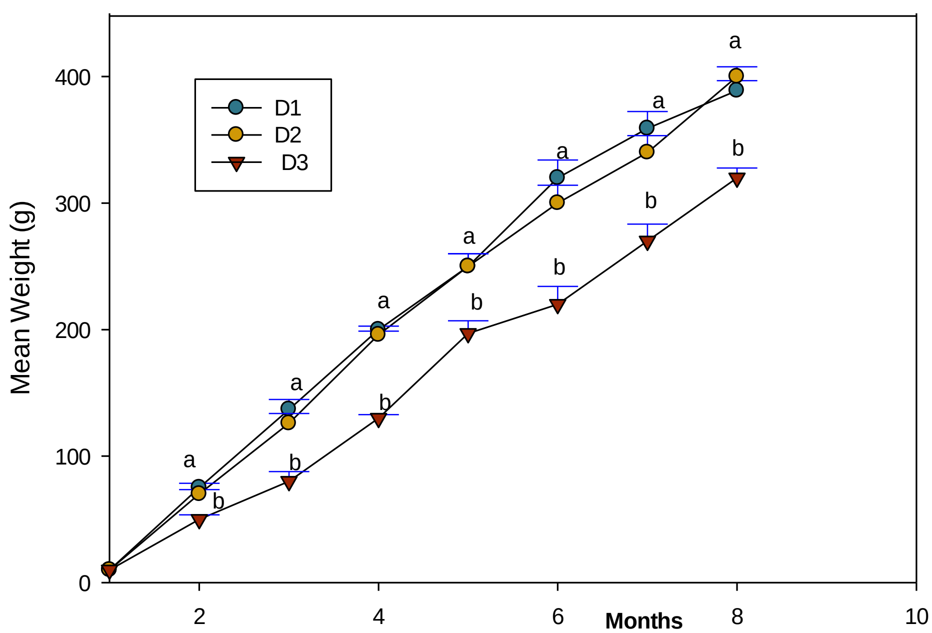

Figure 7: Means fish weight and standard deviation during the GIFT tilapia culture experiment. Different letters indicate significant differences between densities at the same time.

Table 6: Mean size and growth performance at different densities. Mean identified by different superscripts are significantly different.

Density fish/m²	3(D1)	3.2(D2)	3.5(D3)
Mean initial weight	10^a	10^a	10^a
Mean final weight	$383±13^a$	$389±27^a$	320^b
SGR	$1.58±0.01^a$	$1.59±0.03^a$	1.50^b
DWG	$383.63±12.503^a$	$389.29±27.429^a$	319.958^b

The survival rates at all densities were greater than 90 percent, but there was no significant difference between treatments (Table 7).

Table 7: Mean and Standard deviation per treatment

Density fish/m²	3(D1)	3.2(D2)	3.5(D3)
Survival (%)	$91.7±1.2^a$	$91.7±0.88^a$	$90.6±0.4^a$

5.2 Food Conversion Ratio

The feed conversion was best in the D1 group and significantly better than at the higher densities (Figure 8).

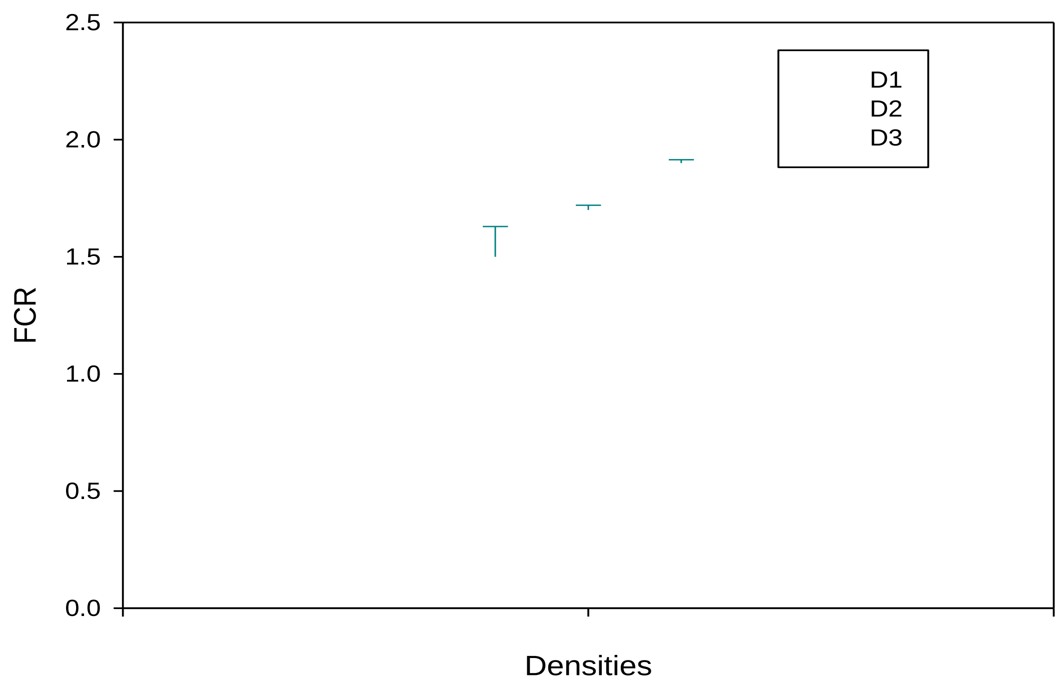

Figure 8: FCR per density.

5.3 Yield

The yield was significantly higher at the intermediate density than at either higher or lower density (Figure 9).

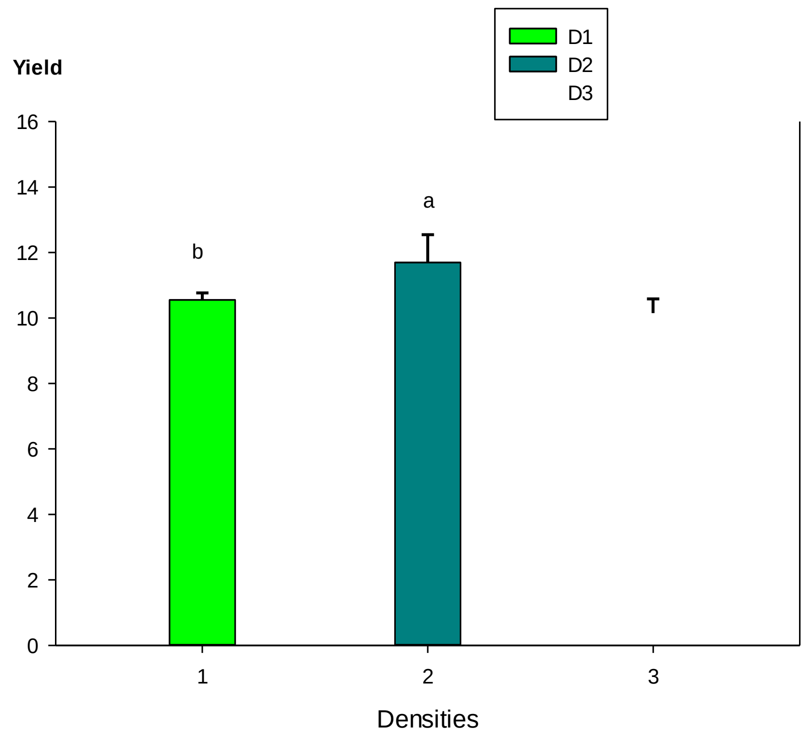

Figure 9: Yield per treatment for GIFT tilapia culture. Different letters indicate significant differences, Holm-Sidak method with $p<0.05$.

5.4 Water quality

During the cultivation, the oxygen decreased progressively in all groups, being more evident at the highest density (Figure 10). The dissolved oxygen concentration was between 5 and 6.7 mg/l in the low and medium density groups and lower at the highest density (3 to 5.2mg/l) (Table 8).

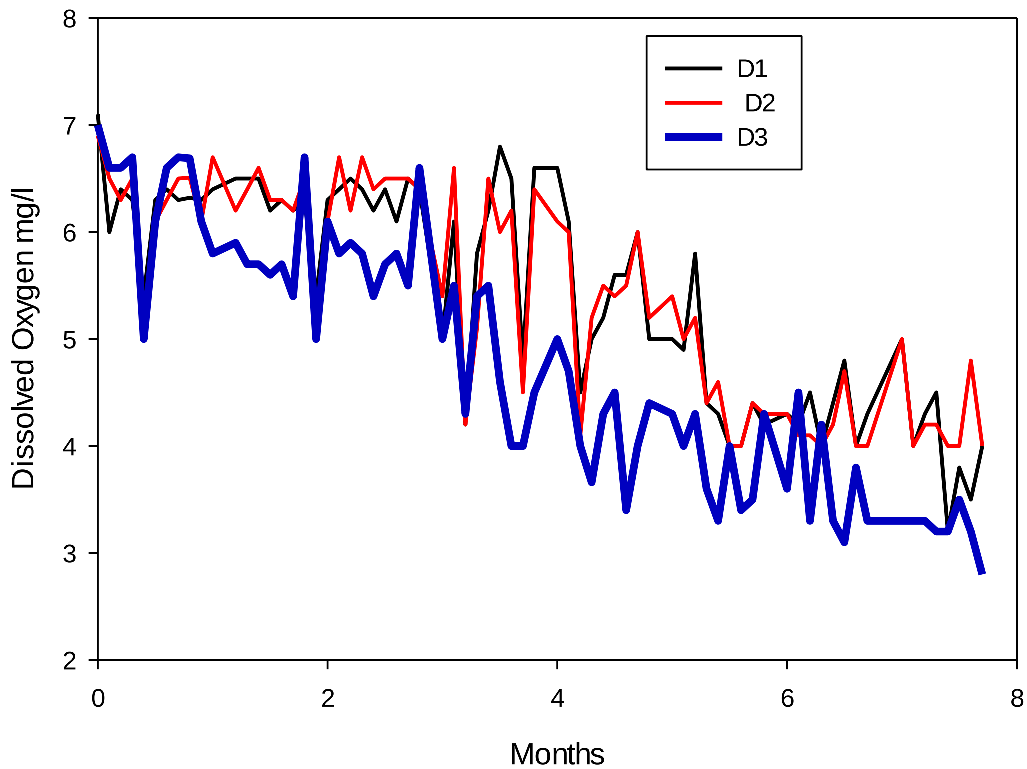

Figure 10: Dissolved oxygen concentration at different densities.

Table 8: Mean and standards deviation for water quality parameter.

Density fish/m²	3	3.2	3.5
Mean Oxygen	5±1.2[a]	5±1.7[a]	4 ±1.2[b]
Mean temperature	25.0	25.5	25.5
Mean pH	7.25±0.12[a]	7.25±0.13[a]	7.0±0.1 [b]

During the farming the pH also is reduced in all groups, but more so at the highest density (Figure 11). The pH for the low and intermediate density were among 7.14 to 7.38. For D3 the values were 6.9 to 7.1. The lower register was 6.8 (Table 9). Temperature in January and February was between 18C°and 19C°early in the morning. During the summer, the temperature increased 24 to 25C°. The highest temperature recorded was 26C°. No significant differences in temperature were noted among ponds.

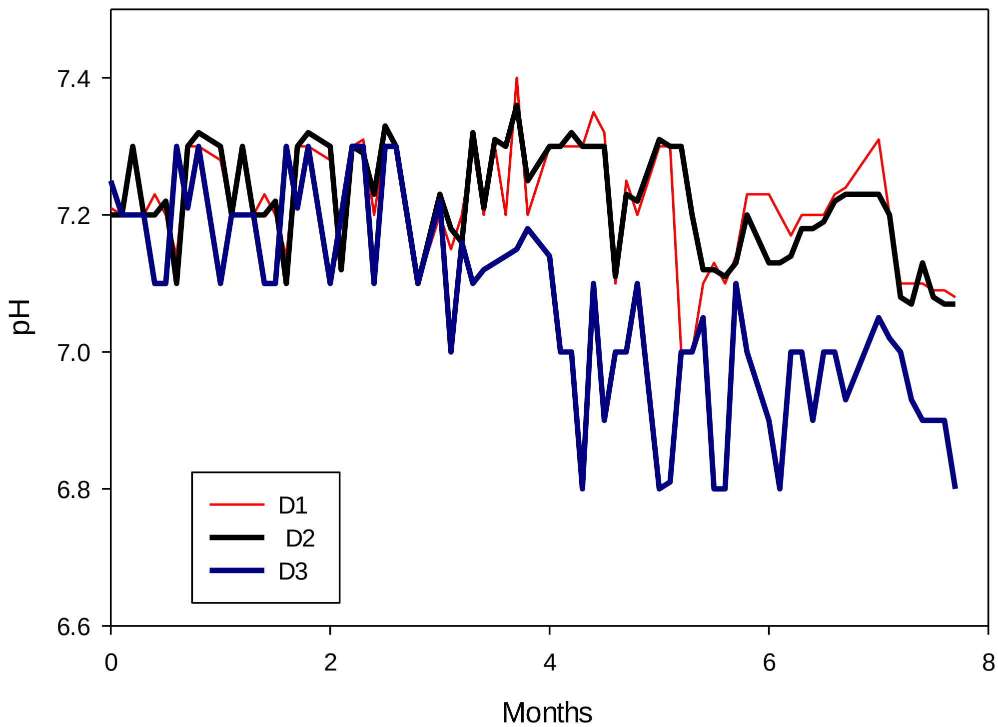

Figure 11: Mean pH at different densities during the experiment.

The simple economy analysis showed that D1 had 38% of net profit contribution while D3 achieved 30%. The higher contribution corresponded to D2 whit 38.8 %.

Table 9: Economy Analysis. (CUP=Cuban peso is the currency in Cuba).

Item	D1	D2	D3
Yield	10552	11695	10149
Price/kg CUP	3.50	3.50	3.50
Gross revenue	36933	40932	35523
Feed used	15720	19367	18749
Cost of feed used	10218	12588	12187
Number of juvenile	30000	32500	35000
Cost juvenile	0.012	0.012	0.012
Cost of fingerlings used	360	390	420
Other costs	12241	12241	12241
Total cost of production	22819	25219	24848
Cost of production / kg	2.16	2.16	2.45
Net Profit contribution	14114	15713	10675
% contribution	38.2%	38.8%	30%

6 DISCUSSION

The growth performance at the low and intermediate density was significantly better than that of fish reared at the highest density. The mean weights of the two former groups was significantly higher than the latter. Based on the summary of studies, this is in disagreement with the majority findings, whom found that greater mean final weight corresponded to the low density and is according with 3 reports, however they conducted the study with different densities.

The stocking density did not affect the survival rates. This may be because the fish were all fairly uniform in size from stocking (10g). Moreover, good care was taken to follow the best practices for the culture and that may also have helped maintaining small sizes variation. This suggests that stocking density might have limited influence on survival. Despite there is no significant different, the survival rate is slightly smaller in the high density D3, concurred with 13 studies.

Since stocking density did not affect survival, differences in yield were primarily determined by stocking density and final size. As a result, the highest yield was obtained at the intermediate density D2 (32 500 fish/ha.). The stocking density affected the yield in D1 and the final size determined the lower production in D3.

From the beginning, the group reared at the highest density grew more slowly than the other two groups. In all groups the water quality was progressively deteriorating, because the biomass was growing and demanding more oxygen, also increasing food offered and the excretion of metabolites, but in the high density was more evident. This may have been caused by reduced growth at the highest density. When early in the morning the oxygen dissolved was nearly 3mg/l, presumably the oxygen depleted at night below 2mg/l causing stress. By increasing water exchange and/or applying aeration the water quality may be improved. In fact, this may allow even higher stocking densities that could increase the yield even further. Also behavioral interaction may have related with the reduction in growth for high density, because at the beginning all groups had good water quality, however the high density showed less growth.

Increased stocking density may have caused stress in the fish which in turn may have reduced the growth at the highest density tested. It is likely that reduced water quality may have contributed to the stress. Also increased stocking density result in competition for space, food and oxygen, increase activity level and fish use more energy deriving in high metabolic rates and then growth decrease. (Ellis *et al.*, 2002). Under culture conditions, the fish for obtain food increase the swimming speed, these activities require energetic cost, which increase due to agonistic interactions. (Thorarensen & Farrell, 2010)

The FCR in this study increased at higher densities. The best feed conversion was found at the lower stocking density. A number of factors may have contributed to the better feed conversion at the lowest density. Natural plankton contributes to the feed intake of tilapia in ponds. The lower the stocking density, the contribution of plankton is greater (Kubitza, 2000). This may have contributed to the reduced FCR in the lower density D1. A second factor contributing to better feed conversion at the lowest density may be related to the behavior of the fish. When stocking density is high, feed loss increases because the high biomass induces water turbulence at feeding time. Tilapia is a visual feeder, so that turbulence affects their access to food and FCR can increase (Chorm & Webster, 2006).

Referred to above summary, this experiment coincides with 5 authors found that FCR rises to with increasing density and is different from 7, they obtained that FCR decreases with increasing stocking density. Despite to FCR are above 2, how as recommended for tilapia farming, it is possible reduce these values. The quality of the feed may also have contributed to the poorer FCR at higher density. The feed was not extruded and, therefore, uneaten feed will sink to the bottom. With extrusion, the feed floats better and longer time is given for the fish to catch it. With reduced feed losses to the bottom, the FCR could improve at the higher densities. In fact, the results of a study by El-Sayed, 2013) suggest that extruded feed gives better FCR (1.0-1.4) than pelleted feed (1.3-1.8).

Many authors abstracted that the effect of increase stocking density may cause various stress responses, such as increase mortality, increase metabolism, reduce growth rate, increase size variation, reduce feed intake, increase FCR, and caused poor health in fish. (Ellis *et al.*, 2002) (Turnbull *et al.*, 2005) (Thorarensen & Farrell, 2010).

The treatment D2 was the optimum stocking density because it achieved the highest amount of fish produced per unit area efficiently. Efficient production means maximum yield that can be produced with adequate feed conversion in less time and with acceptable final weight for consumer, considering that the demand for final weight in Cuba are between 300-350 grams.

If the gross revenue for sales are greater than the total production cost, it means that profit are generated for these densities, D2 allows bigger net profit contribution, enabling the rapid return on investment for infrastructure and equipment used in the fish farm.

7 CONCLUSION AND RECOMEMDATIONS

According to the current best practice directions (POW), the stocking density of GIT tilapia in ponds should be 2.7 fish/m^2 in the first growth-out phase. However, the results of the present study suggest that this could be increased to 3.25 fish/m^2. The latter density gives about 10% higher yield. In the fish farm La Juventud will not be possible to reach high yield through the increase in density, if not is applied mechanical aeration combined with water exchange, so as to increase water quality. Moreover, if the quality of feed is improved or has ensured the stable supply of extruded foodstuff, may lead to decreased production costs and attain more efficiency cultivation.

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APPENDIX

Ponds	Fish/m²	Fish/ha	Fish/ponds	Final weight	Total production	Yield/ha	FCR	% Survival
A1	3	30 000	60 000	398	21600	10.800	1.62	90
A2	3			378	20790	10.395	1.60	92
A3	3			375	20923	10.461	1.38	93
B1	3.2	32 500	65 000	421	25300	12.65	1.73	92
B2	3.2			374	22842	11.421	1.67	92
B3	3.2			373	22027	11.0135	1.71	91
C1	3.5	35 000	70000	320	19296	9.648	1.77	86
C2	3.5			320	20800	10.400	1.90	93
C3	3.5			320	20800	10.400	2.07	93