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Florida Department of Natural Resources

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ABSTRACT

Willis, S. A., W. K. Havens, and R M. Ingle. 1976. Quality Improvements of Oysters, *Crassostrea virginica* (Gmelin), Using Artificial Foods. Fla. Mar. Res. Publ. No. 20. 16 pp. Methods of improving oyster condition using artificial foods in flow-through and recirculating water systems were evaluated. Finely ground cornmeal produced glycogen increases from 0.62 to 6.68% in two weeks. The flow-through system provided best water quality; two layers of oysters allowed optimal usage of tank space; and smaller oysters fattened more rapidly than did larger ones. Seasonal procedures are recommended for best oyster fattening. High quality oysters (11.9% glycogen) were produced during summer conditions using the artificial fattening procedure.

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CONTENTS

INTRODUCTION

Success of mariculture ventures is often directly related to proper species selection. Species should exhibit good growth under local environmental conditions, be relatively easy to culture through all life cycle phases, and have good market potential (Bardach et al., 1972). The American oyster, *Crassostrea virginica* (Gmelin), has been cultured along the eastern United States seaboard since the mid 1950s (Galtsoff, 1964). Its life cycle is well known and numerous hatcheries are already in existence. In addition, oyster market value has steadily risen for many years due to increasing consumer demand and reduced harvests (Matthiessen, 1971).

Oyster culture in Florida is especially attractive because growth is rapid due to higher water temperatures. Ingle (1950, 1951) reported 10 cm of growth for freshly set oysters during 31 weeks of warm weather and an average growth of 12.7 cm for the first two years at Apalachicola, Florida. In a study of pumping, growth, and mortality rates, Collier (1954) found the optimal temperature range for oysters in this region to be 15-25°C. He also noted that water temperature in the northern Gulf has been over the maximum of 25°C throughout summer and fall since 1916.

High temperatures are not totally beneficial and can actually debilitate oysters by prolonging spawning. Spawning causes a reduction in meat quality, flavor and color, loss of solid weight, and a decrease in meat volume (Kinne, 1963; Sakuda, 1966; Galtsoff, 1964; and others) Spawning may also contribute to a reduction in disease resistance which, when coupled with increased prevalence of pathogens during warm weather, results in annual mortality as high as 60% of the adult stock (Quick and Mackin, 1971). Therefore, North Florida oysters are in prime condition for only 4-5 months (December to April). The legal season for harvesting oysters in Florida is from September 1 to May 31.

In Florida, a primary factor prohibiting oyster harvests during summer is poor oyster condition. Implementation of modern aquacultural methods using an oyster fattening system would allow oystermen to capitalize on rapid growth and produces a consistently high quality product year round. Such a fattening procedure can be compared with final-stage feed lot fattening to boost cattle condition using grain feeds just prior to slaughter. This would also eliminate seasonality in the oyster industry thus fostering year-round employment. Whitfield (1973) found that in Franklin County (Apalachicola), where 80% of the Florida oyster industry is located, 46% of the annual per capita income is derived from oyster related work.

The natural diets of oysters have traditionally been investigated by stomach content analysis (Dean, 1887; Lotsy, 1895; Hunt, 1925; and others). The main oyster dietary components have been reported to be diatoms, detritus, nanoplankton, or combinations of all three. The controversy of what actually constitutes a natural oyster diet, however, is still unresolved (Galtsoff, 1964). Production of marketable oysters under laboratory conditions using such diets, particularly algal cultures, has been tested for many years and found to be uneconomical (Gillespie et al., 1964; Dunathan et al., 1969; Hidu, 1969). Basic problems with these diets include difficulty of culture maintenance and high cost of food production.

Artificial foods have long been considered as alternatives to natural diets (Galtsoff, 1964; Ukeles, 1970) One characteristic of oyster condition is glycogen content, colloquially termed fat. Glycogen is the main storage polysaccharide of oysters and is responsible for their creamy white color and distinct flavor. It is a polysaccharide of D-glucose and so important for marketing considerations that early investigators examined the direct uptake and utilization of simple sugars in oyster metabolism. Mitchell (1916) found that dextrose is absorbed by the oyster, rapidly converted to glycogen, and stored. Yonge (1928) found *Ostrea edulis* averaged an uptake of 9 mg of glucose/oyster/h and zero uptake when the mouth was plugged with paraffin. Oysters apparently assimilate small quantities of simple sugars through the alimentary canal and via phagocytosis on the mantle (Galtsoff, 1964; Owen, 1966). This uptake however, does not significantly increase glycogen content (Gillespie et al., 1964). Studies on direct uptake of dissolved sugars initiated further work to find carbohydrate substances of particle sizes compatible with oyster filtration (Loosanoff and Engle, 1947; Jorgenson, 1960; Haven and Morales-Alamo, 1964). Gillespie et al. (1964) used various grains, algae, and bacteria in a series of screening experiments. Best oyster fattening occurred when whole ground rice and whole ground cornmeal were suspended in water and fed to oysters. Haven (1965) used cornstarch with limited success in fattening oysters. Dunathan et al. (1969) determined that food with 65-75% carbohydrate content produced rapid biodeposition of glycogen.

Five experiments utilizing artificial diets were conducted from September 1971 to January 1973 to study various aspects of commercial application of oyster fattening techniques. This report evaluates food types and amounts, system designs, water management and seasonal variations in procedures required to fatten oysters and yield a readily marketable product.

METHODS AND MATERIALS

Adult oysters, 6-12 cm, were obtained from Cross Bayou, Seminole, Florida. Collections were made during low tides and only subtidal oysters gathered to reduce variation in initial condition. Oysters were washed free of mud, and encrusted organisms removed to prohibit food competition by them during nutritional experiments.

Oysters were slowly acclimated to laboratory conditions in 7-14 days and selected for experimentation when new shell growth was observed. Experiments were conducted in a concrete block building which housed four 0.76 x 2.74 x 0.46 m tanks, plywood and epoxy construction, and two 0.76 x 1.22 x 0.46 m PVC lined tanks all with PVC plumbing. Water was delivered from Bayboro Harbor, Tampa Bay, to flow-through and recirculating systems at a constant rate of 6 turnovers/day and splashed into the center of each tank to provide additional aeration. Temperature and dissolved oxygen were monitored daily in each tank with a YSI meter. Air stones were used to maintain a recommended minimum of 2.5 ml/l (3.5 mg/l) dissolved oxygen (Korringa, 1952). Salinity was monitored daily with an AO Goldberg temperature compensating refractometer. No temperature or salinity adjustments were made during the experiments. Both artificial and natural light were incident on the tanks during daylight hours only.

Feeds were ground in a stone ball mill and determined microscopically to have a size range of 5-40 μm with an average particle size of 20 μm. To facilitate grinding, water in the grains was removed by oven drying at 60°C. This low temperature helped maintain nutrient intergrity. Daily feed rations were homogenized in a Waring blender and diluted with 37.85 l of water in a plexiglass feeding cone. Suspension of the food material was maintained by three airstones. This suspension was dripped slowly into each tank over an 8-h period. Flow was regulated by a screw clamp and visual examination used to determine necessary adjustments. Two feedings were made daily.

Whole yellow cornmeal and hominy were selected as the two basic artificial diets based on previous oyster fattening research (Gillespie et al., 1964; Dunathan et al., 1969). Food cost, availability in commercial quantities, and labor required to grind feed to appropriate particle size were criteria in experimental food selection. A protein additive, brewer's yeast, was combined with the basic diets in experiments I and III to compare relative oyster improvements. Brewer's yeast is an inexpensive protein source, rich in amino acids, minerals, and B-complex vitamins.

The five experiments each had a duration of 6 weeks and ran consecutively. Modifications implemented at the beginning of each experiment were based on preceding results. Twelve oysters were randomly sampled, grossly examined, and tested for glycogen content and percent dry weight (total solids) during experiments I and V at 0, 2, 4, and 6 weeks, and during experiments II, III, and IV at 0, 3, and 6 weeks. Glycogen content was determined by the techniques of Calderwood and Armstrong (1941) and Seifter et al. (1950), as modified for this project by Burklew (1971). Glycogen values were determined colorimetrically with a Bausch and Lomb Spectrophotometer 70. Percent dry weight was recorded after drying samples at 80°C for 48h. Volume measurements based on number of shucked oysters/l were made during experiments I, II, and V at 0 and 6 weeks, and during experiments III and IV at 0, 3, and 6 weeks.

Field controls were maintained during experiments I, IV, and V for comparison with laboratory control and experimental oysters. These controls were collected from the same area and treated the same as experimental oysters. They were held in 66 x 66 cm plastic Nestray shellfish growout trays with a capacity of 75-100 oysters each. Trays were stacked three high, in subtidal running water at the collection site. Field water quality was monitored once weekly and oyster sampling made at same intervals as on laboratory-held oysters.

Experiment I, September-November 1971, compared three artificial diets; cornmeal, hominy, and hominy with yeast additive. Diets were fed to oysters at a rate of 0.27 g/oyster/day; tanks were drained and cleaned once daily, and stocked with 300 oysters in one layer.

Experiment II, December 1971 - January 1972, compared flow-through and recirculating water systems to determine differences in water management and feeding rates. Ground cornmeal was the only diet used. Three flow-through and three recirculating tanks were used, each group with a non-fed control, a 0.2 g/oyster/day feeding regime, and a 0.4 g/oyster/day regime. Each tank was stocked with 300 oysters in one layer and drained and cleaned every other day.

In experiments III, IV, and V, 600 oysters in two layers were used to investigate maximum system productivity.

In experiment III, March-April 1972, cornmeal was fed at rates of 0.45-0.50 g/oyster/day in three flow-through tanks and 0.30 g/oyster/day in one recirculating tank. A yeast supplement (1:8) was added to the diet in one flow-through tank. Each tank was drained and cleaned once daily.

Experiment IV, June-August 1972, was designed to study oyster fattening during summer conditions in a flow-through system. Two six-week groups were fed cornmeal at 0.3 and 0.5 g/oyster/day and cleaned once daily; two three-week groups were fed cornmeal at 1.0 and 1.2 g/oyster/day and cleaned twice daily.

Experiment V, November 1972-January 1973, was designed to investigate variation of glycogen content with oyster size, recorded as right valve height measured from umbo to lip. Oysters were fed cornmeal at 0.5 and 1.0 g/oyster/day in flow-through tanks and cleaned once daily.

RESULTS

EXPERIMENT I

Initial oyster condition appeared very poor, meats were watery and filled only 50% of the mantle cavity and color was a translucent gray. There was little evidence of gonadal development or glycogen deposition (Table 1). In the laboratory tanks salinity varied 21-24‰ and temperature 24-30°C (Figure 1). At the field control site variations of 4-22‰ and 23-30°C were recorded.

After two weeks, percent glycogen increased in oysters fed cornmeal and hominy and decreased in yeast-hominy and lab control oysters. Mortalities were high in all groups except those fed cornmeal.

During the third week natural spawns occurred in all tanks. Only oysters fed hominy exhibited glycogen and dry weight increases at the four week sampling interval (Figure 4). Mortalities were again lower in the group fed cornmeal.

Rapid glycogen increases were found in all oysters during the four to six week period. Final tests demonstrated greatest glycogen increases with hominy (10.08%) followed by cornmeal (9.85%). Oysters fed cornmeal had the highest final percent dry weight (17.0%) and lowest mortality (2.7%). Oysters fed hominy had a final volume of 72 oysters/l compared with 110 oysters/l for field controls (Figure 2),

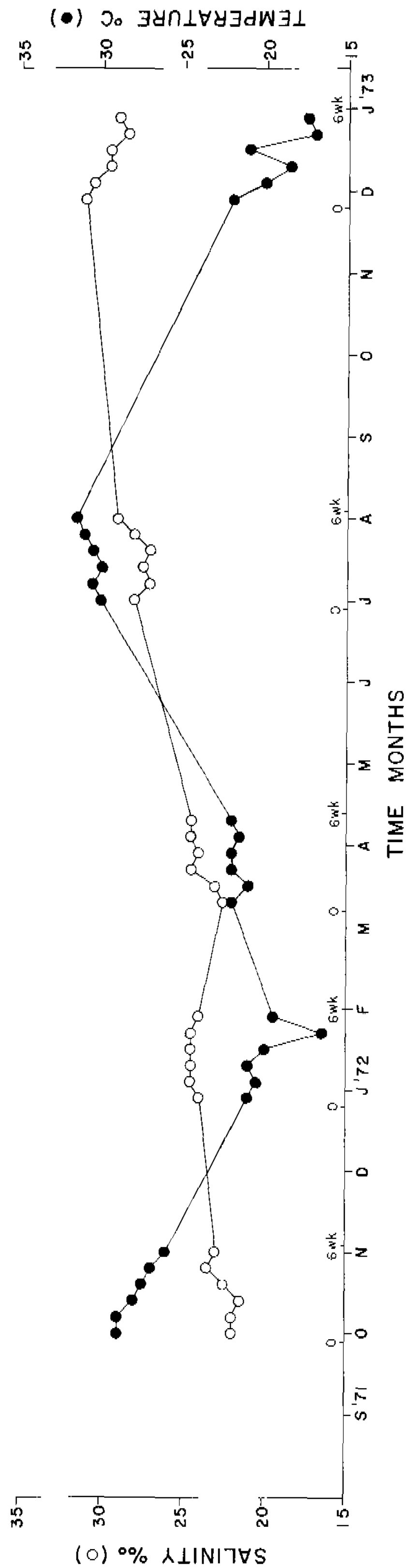

Figure 1. Experiments I-V: Salinity and temperature vs. time.

representing a 34.6% increase in meat volume. This was also a 41.9% increase over the initial volume of 128 oysters/l.

EXPERIMENT II

Oysters collected for this experiment reflected the good characteristics of winter oysters. Initial volume was 87 meats/l, percent glycogen was 3.99%, and color condition was fair. Salinity varied 20-26‰ during the experiment; temperature varied 7-22°C in the flow-through system and 20-28°C in the recirculating system (Figure 1).

After three weeks, best results occurred in the 0.4 g/oyster/day flow-through tank. Both recirculating groups had glycogen increases, but very high mortality (Table 2).

Best results at the six week termination point continued in the 0.4 g/oyster/day flow-through tank. Final glycogen content was 8.09% with only a small increase found for the last three weeks Percent dry weight increased to 22.8%; meats filled the mantle cavity forcing the shell open when the adductor muscle was severed. Volume was 62 meats/l, a 28.8% increase over the initial value.

Oysters in the recirculating tanks did poorly compared with flow-through system oysters. Final glycogen values were good. Again glycogen increases were negligible during the last three weeks of testing; moreover, dry weight percent actually decreased. Final vol-

TABLE 1. EXPERIMENT I, SEPTEMBER 1971 - NOVEMBER 1971

Group	Regime	Glycogen (Wet Weight) %	Dry Weight (Total Solids) %	Volume Shucked (meats/one liter)	Visual Condition of Meats	Mortal-ities
Initial	....	2.67	11.3	128	Very Poor	....
TANK 1	Lab control, non-fed					
2 wk		1.24	11.0	....	Poor	14
4 wk		2.48	10.2	....	Poor	3
6 wk		2.88	9.6	100	Poor-Fair	2
TANK 2	Fed 0.2g hominy and 0.067g yeast/oyster/day					
2 wk		2.00	14.2	....	Fair	10
4 wk		3.05	15.6	....	Poor-Fair	7
6 wk		6.75	15.2	84	Fair-Good	2
TANK 3	Fed 0.267g cornmeal/oyster					
2 wk		4.67	13.8	....	Fair	4
4 wk		3.76	15.3	....	Fair	1
6 wk		9.85	17.0	80	Good	3
TANK 4	Fed 0.267g hominy/oyster/day					
2 wk		4.95	13.0	....	Fair	13
4 wk		6.35	16.8	....	Fair	7
6 wk		10.08	15.9	72	Good	2
FIELD	Field-held control, non-fed					
2 wk		3.23	12.9	....	Poor	5
4 wk		2.75	13.2	....	Poor	2
6 wk		3.42	13.4	110	Poor	0

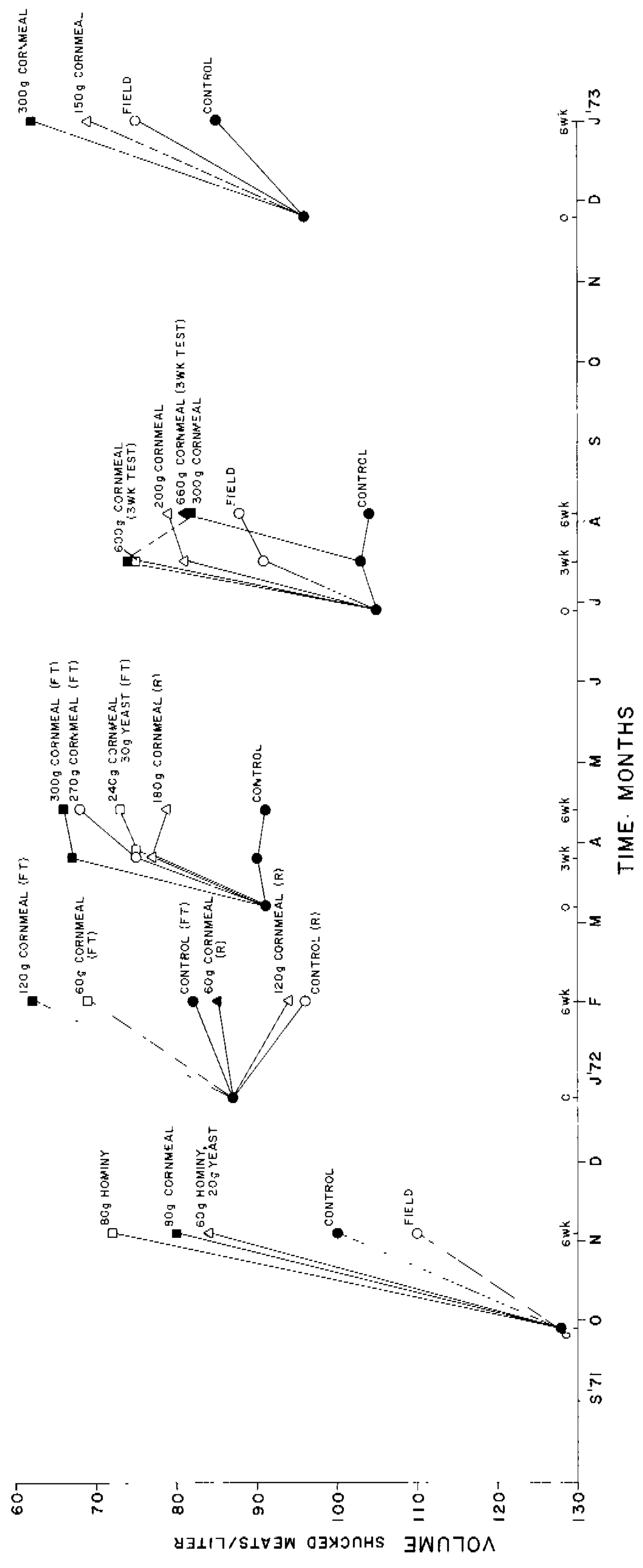

Figure 2. Experiments I-V: Volume of shucked oyster meats vs. time.

ume was 85 meats/l for oysters fed 0.2 g/oyster/day.

EXPERIMENT III

Initial oyster condition appeared poor-fair. Some gonadal development was observed in shellfish sampled, meats were watery, filling 50% of the mantle cavity (Table 3). Temperature varied 16-24°C and salinity varied 21-26‰ during the experiment (Figure 1). At the end of three weeks, consistent losses in all categories were found in the non-fed control with all other groups exhibiting increases. Best results were found in the 0.5 g cornmeal/oyster/day group. Again, mortalities were high in the recirculating system.

Final results were best in the 0.5 g cornmeal/oyster/day flow-through group. Glycogen was 12.98%, dry weight was 24.8%, and volume was 66 meats/l. In the recirculating tank, glycogen decrease and high mortality indicated that cornmeal fattening was not feasible in this type system, thus precluding further use.

EXPERIMENT IV

Initial oyster condition appeared poor, no shell growth was evident and meats were a translucent gray-brown color filling 50% of

TABLE 2. EXPERIMENT II, DECEMBER 1971 - JANUARY 1972

Group	Regime	Glycogen (Wet Weight) %	Dry Weight (Total Solids) %	Volume Shucked (meats/one liter)	Visual Condition of Meats	Mortalities
Initial	... ..	3.99	18.6	87	Fair	....
TANK 1	Flow-through, control/non-fed					
3 wk		2.78	18.0	....	Fair	0
6 wk		2.10	16.9	82	Good	0
TANK 2	Flow-through, fed 0.2g cornmeal/oyster/day					
3 wk		3.84	19.0	....	Fair	0
6 wk		4.64	19.0	69	Very Good	0
TANK 3	Flow-through, fed 0.4g cornmeal/oyster/day					
3 wk		7.17	20.8	....	Fair	4
6 wk		8.09	22.8	62	Very Good	0
TANK 4	Recirculating control non-fed					
3 wk		4.10	18.0	....	Fair	0
6 wk		2.88	15.8	96	Fair	1
TANK 5	Recirculating fed 0.2g cornmeal/oyster/day					
3 wk		6.20	21.2	....	Fair	2
6 wk		6.16	19.8	85	Fair	5
TANK 6	Recirculating fed 0.4g cornmeal/oyster/day					
3 wk		6.30	19.8	....	Fair	16
6 wk		6.75	19.6	94	Poor-Fair	20

the mantle cavity. The initial glycogen content was disproportionately high due to excessive liquid loss when shucked (Table 4). Temperature varied 27-32°C with a mean of 30.8°C and salinity varied 26-31‰ with a mean of 27.9‰ (Figure 1).

For experiments I, II, and III, mortality rates were generally higher and glycogen and dry weight increases minimal during the latter three weeks of testing (Tables 1, 2, and 3). Because higher food concentrations also proved more efficient in fattening oysters (Tables 2 and 3), two groups in experiment IV received high food concentrations for a duration of only three weeks.

Oysters in both six week regimes (0.33 and 0.50 g/oyster/day each had glycogen increases, dry weight decreases, and high mortalities for the first three week period. At the end of six weeks, both groups exhibited glycogen and dry weight increases (Figures 3 and 4).

The high food concentration-short duration group, fed 1.0 g/oyster/day, had gains in glycogen, an increase in dry weight, and low mortality. The second high food concentration-short duration group, fed 1.32 g/oyster/day, attained a glycogen increase from 1.28% to 7.11%.

EXPERIMENT V

Initial oyster condition appeared poor with little or no glycogen or gonadal development evident. No new shell growth was found and meats were watery, filling only 50% of the mantle cavity (Table 5). Temperature varied

TABLE 3. EXPERIMENT III, MARCH 1972 - APRIL 1972

Group	Regime	Glycogen (Wet Weight) %	Dry Weight (Total Solids) %	Volume Shucked (meats/one liter)	Visual Condition of Meats	Mortalities
Initial		4.50	17.6	91	Poor-Fair	Layer: (T) Top (B) Bottom
TANK 1	Flow-through lab control non-fed					
3 wk		2.85	15.4	90	Fair	No layers
6 wk		2.26	18.9	91	Fair	No layers
TANK 2	Flow-through, fed 0.45g corn-meal/oyster/day					
3 wk		7.03	19.4	75	Fair	T: 2 B: 5
6 wk		7.50	25.3	68	Good	T: 40 B: 43
TANK 3	Flow-through, fed 0.4g cornmeal and 0.05g yeast/oyster/day					
3 wk		8.18	20.1	75	Fair	T: 5 B: 5
6 wk		7.77	23.2	73	Good	T: 37 B: 30
TANK 4	Flow-through, fed 0.5g cornmeal/oyster/day					
3 wk		12.06	23.0	67	Fair	T: 7 B: 7
6 wk		12.98	24.8	66	Very Good	T: 36 B: 33
TANK 5	Recirculating, fed 0.3g cornmeal/oyster/day					
3 wk		9.28	20.2	77	Fair	T: 15 B: 15
6 wk		7.88	21.0	79	Good	T: 40 B: 50

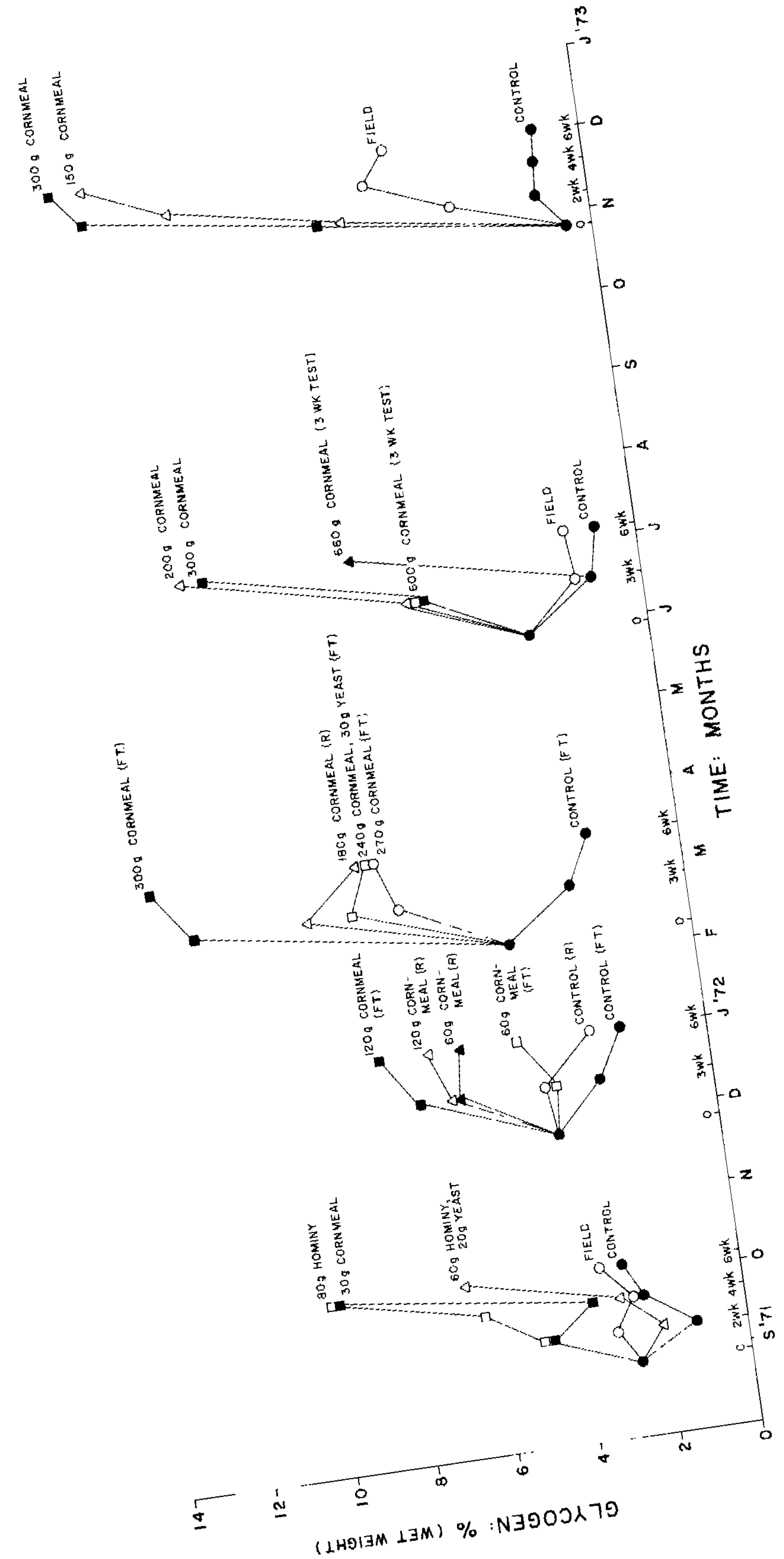

Figure 3. Experiments I-V: Percent glycogen vs. time.

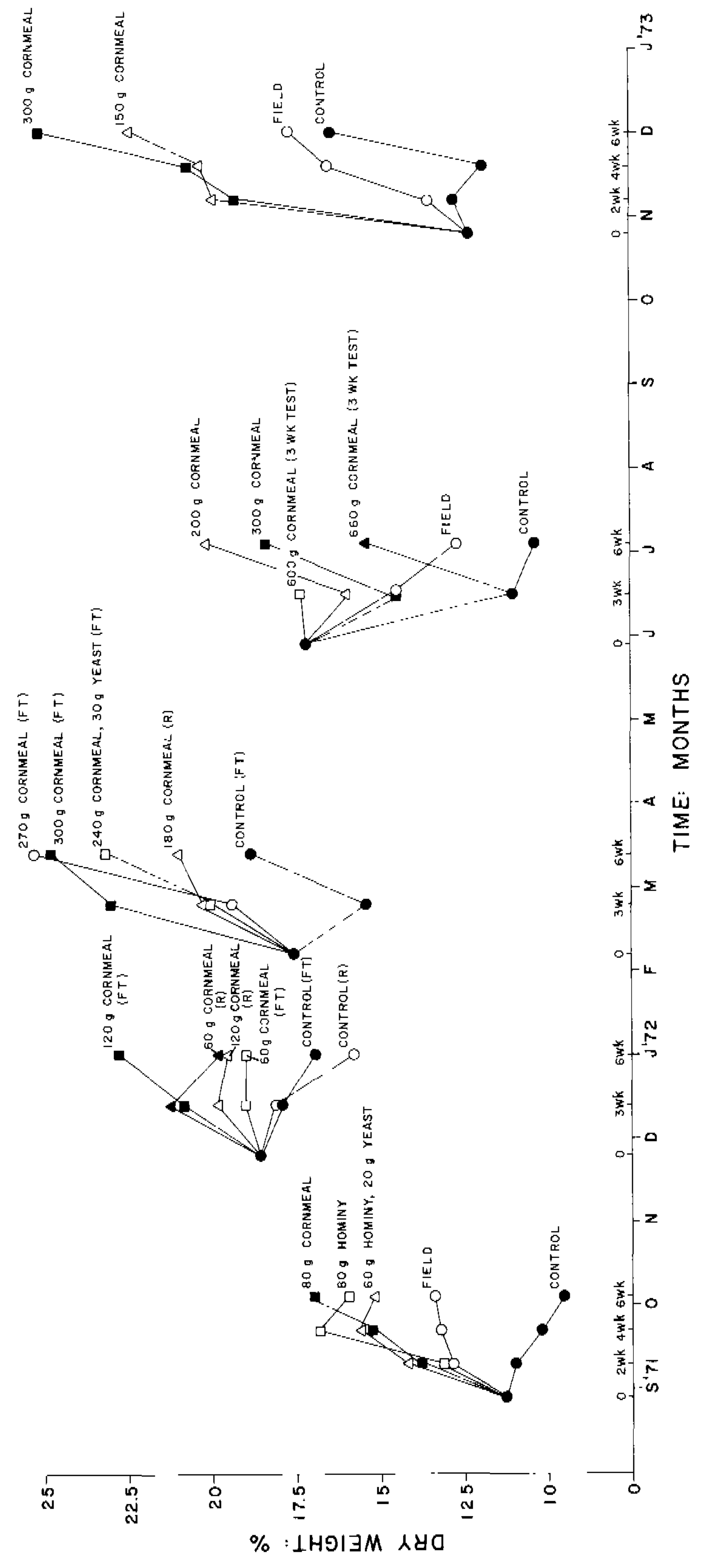

Figure 4. Experiments I-V: Percent dry weight vs. time.

16-25°C and salinity 27-32‰ in laboratory tanks (Figure 1) and 16-25°C and 10-28‰ at the field control site.

At two weeks, oysters fed 0.5 and 1.0 g cornmeal/oyster/day had extremely rapid glycogen increases from 0.62 to 6.06% and 6.68%, respectively. Glycogen deposition continued and after four weeks the 1.0 g/oyster/day group had attained 12.33% glycogen. Final tests showed excellent increases in the 1.0 g/oyster/day group with 13.02% glycogen, 25.1% dry weight, and a final volume of 62 meats/l.

DISCUSSION

This project was designed to evaluate improvements in adult oyster quality using artificial diets. Cornmeal consistently gave best glycogen, dry weight, and volume increases with low mortality. Cornmeal was readily available, economical, and easily ground to a size (5-40 μm) appropriate for oyster filtration. Addition of yeast supplements did not enhance oyster quality (Tables 1 and 3). This is supported by Loosanoff (1949) who found undigested yeast cells in oyster feces.

Flow-through water systems allowed maintenance of large numbers of oysters in small tanks with good water quality. Lack of water exchange in recirculating systems allowed accumulation of uningested food, pseudofeces, and metabolic wastes resulting in poor oyster fattening, high mortality, poor meat quality, and feeding inhibition (Tables 2 and 3; Figures 2 and 3).

To investigate optimal utilization of the water column, oysters were arranged in one

TABLE 4. EXPERIMENT IV, JUNE 1972 - AUGUST 1972

Group	Regime	Glycogen (Wet Weight) %	Dry Weight (Total Solids) %	Volume Shucked (meats/one liter)	Visual Condition of Meats	Mortalities
Initial		2.91	17.2	105	Poor	Layer: (T) Top (B) Bottom
TANK 1	Lab control, non-fed					
3 wk		1.28	11.0	103	Poor-Fair	T: 18 B: 21
6 wk		1.05	10.4	101	Poor-Fair	T: 17 B: 18
TANK 2	Fed 0.33g cornmeal/ oyster/day					
3 wk		5.79	16.2	81	Good	T: 22 B: 32
6 wk		11.19	20.2	79	Fair-Good	T: 25 B: 35
TANK 3	Fed 0.5g cornmeal/ oyster/day					
3 wk		5.85	14.6	74	Fair-Good	T: 28 B: 28
6 wk		10.67	18.4	82	Fair-Good	T: 32 B: 37
TANK 4	Fed 1.0g cornmeal/ oyster/day					
3 wk		5.86	17.4	75	Good	T: 16 B: 22
TANK 5	Fed 1.32g cornmeal/ oyster/day					
3 wk		7.11	15.4	81	Good	T: 11 B: 20
FIELD	Field-held control, non-fed					
3 wk		1.60	14.6	91	Poor-Fair	
6 wk		1.80	12.7	88	Poor-Fair	

and two layers. There was slight variation in mortality between layers during experiments III-V (Tables 3, 4, and 5). Effects of reduced light on the bottom layers were considered minimal for our feeding experiments. Loosanoff and Nomejko (1946) and Galtsoff (1964) reported no difference in oyster filtration rates with light variation; Medcof and Kerswill (1965), comparing groups of oysters exposed to either light or shade for six months, found the former to have fatter meats and the latter to have more linear shell growth.

Experiment V illustrated that small oysters (≤8.0 cm) had consistently higher per-

TABLE 5. EXPERIMENT V, NOVEMBER 1972 - JANUARY 1973

Group	Regime	Glycogen (Wet Weight) %	Dry Weight (Total Solids) %	Volume Shucked (meats/one liter)	Visual Condition of Meats	Mortalities
Initial		0.62	12.4	96	Poor	Layer: (T) Top (B) Bottom
TANK 1 2 wk	Lab control, non-fed	1.55	12.8	......	Poor	T: 0 small 2 large B: 0 small 0 large
4 wk		1.52	11.9	......	Poor	T: 1 small 1 large B: 0 small 1 large
6 wk		1.26	16.4	85	Fair	T: 1 small 0 large B: 2 small 0 large
TANK 2 2 wk	Fed 0.5g cornmeal/ oyster/day	6.06	19.9	......	Fair-Good	T: 0 B: 0
4 wk		10.25	20.4	......	Good	T: 1 small 2 large B: 2 small 0 large
6 wk		12.26	22.4	69	Good	T: 1 small 0 large
TANK 3 2 wk	Fed 1.0g cornmeal/ oyster/day	6.68	19.3	......	Good	T: 1 small 1 large B: 0 small 1 large
4 wk		12.33	20.7	......	Good	T: 2 small 1 large B: 0 small 2 large
6 wk		13.02	25.1	62	Very Good	T: 2 small 2 large B: 1 small 0 large
FIELD 2 wk	Field-held control, non-fed	3.39	13.6	......	Fair	No layers 1 large
4 wk		5.46	16.6	......	Fair	2 large 1 small
6 wk		4.89	17.7	75	Fair-Good	1 large 1 small

cent glycogen increases than larger oysters (>8.0 cm) under identical conditions. At the two and four week intervals, 91.3% of the small oysters had a higher glycogen content than the large ones. Potential value to the half-shell trade of small, readily fattened oysters is evident; artificially fattened oysters were also consistently superior to field samples (Tables 1, 4, and 5). Oyster fattening and mortality rates were dependent on temperature (season) and feeding concentration. This led to the development of seasonally optimized feeding regimes.

Florida oysters are generally in poor, unmarketable condition during early September when water temperature is still warm enough to induce spawning. According to most oystermen, harvest during this time of year requires considerable time and effort and is mostly unprofitable. They harvest, however, to establish business accounts early in the season and satisfy consumer demand. This demand coupled with low natural mortalities indicated that an artificial feeding regime of 0.75-1.00 g/oyster/day and once daily cleaning would produce the quality product desired.

Oysters are in their best condition during winter with glycogen, dry weight, and meat volume being maximal. Data from experiments II and V showed that artificial feeding techniques could further fatten a winter oyster, but such enhancement of good quality wild stock appears unnecessary.

During spring, oyster condition is generally good. Glycogen content remains high until late spring when spawning commences (Galtsoff, 1964; Finucane and Campbell, 1968). Oysters continue to be commercially attractive because the color of glycogen and gonadal tissue are very similar, making visual distinction difficult. Best final results were obtained in the spring fattening experiment, but mortality was high the final three weeks. Therefore, a three week fattening period is suggested with a 1.00 g/oyster/day feeding rate and once daily cleaning.

Experiment IV illustrated that even under summer conditions (Figure 1) oysters can be successfully fattened (Table 4). Many workers have found that some oyster physiological functions are optimal during warm weather. Galtsoff (1928) found optimal gill activity between 25-30°C, and Loosanoff (1958) observed a maximal pumping rate at 29°C. Such increases in oyster metabolism due to high temperature are beneficial if food is sufficient (Collier, 1959). Dunathan and Ingle (personal communication) fed cornmeal to oysters at elevated temperatures (17-28°C) and found excellent glycogen deposition at 26°C. Studies by Collier et al. (1950, 1953) and Collier (1959) demonstrated oyster filtration is dependent on seawater carbohydrate concentration and a direct relationship exists between temperature increase and carbohydrate requirement. Although fattening rate was consistent during experiment IV, high mortality indicated that fattening should be accomplished in three weeks. Therefore, a fattening regime of 1.00-1.32 g/oyster/day, twice daily tank cleanings, and maintenance of dissolved oxygen above 2.5 ml/l (3.5 mg/l), 50% saturation at 25‰, 25°C is recommended for summer.

Our data show the oyster season could include summer months if artificial feeding methods are used to enhance oyster quality. Benefits of such a seasonal extension with the introduction of aquacultural methods would be year-round employment in the oyster industry and a continuous supply of quality oysters.

SUMMARY

1. Comparisons of oyster quality improvements were made on groups fed hominy, cornmeal, cornmeal-yeast, and hominy-yeast. Cornmeal consistently produced rapid increases in glycogen, dry weight, and meat volume. Yeast supplementation did not significantly improve oyster quality.
2. Comparison of field and lab held oysters illustrated the rapid and consistent improvements using artificial diets.
3. The flow-through system was superior to the recirculating system producing better quality oysters in a shorter period with lower mortality.
4. More rapid fattening and lower mortality

were found during the first three weeks as compared to the final three weeks.

5. More efficient utilization of tank space was accomplished using two layers of oysters; no significant variation in mortality of glycogen was noted.
6. Adaptations in feeding amount, tank cleaning, and dissolved oxygen content were made to compensate for seasonal temperature differences.
7. Summer fattening of oysters was feasible using artificial feeding regime. The key factor is not temperature but availability of suitable food.
8. An inverse relationship existed between oyster size and glycogen content after feeding cornmeal for two and four weeks.

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