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Survival and reproductive characteristics of *Artemia franciscana* Kellogg 1906 strains from Yucatan, Mexico populations, cultivated at different salinities (40, 60, 80, 100 and 120 gL^{-1}).

Sobrevivencia y características reproductivas de las poblaciones de *Artemia franciscana* Kellogg, 1906 provenientes de Yucatán, México, cultivadas a diferentes salinidades (40,60, 80, 100 y 120 gL^{-1}).

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ABSTRACT

Artemia can survive in habitats that have a wide salinity range (10 gL^{-1} to 340 gL^{-1}) conditions, but this can modified the reproductive characteristics of different *Artemia* species or populations. That's why this study with four strains from Yucatan peninsula habitat (CAN, CEL, RSAL and CRIS) was made. 0.5 g of cysts from each strain were hatched and nauplii were cultured in 200 L plastic beakers with 160 L of salt water (40, 60, 80, 100, 120 gL^{-1}). The organisms were fed with *Tetraselmis* sp. and *Pinnularia* sp. microalgae's until the organisms reach pre adult stage. 15 pairs of couples (1 female /2 males) were formed in 200 mL beakers from each population. Every day, the couples were observed to determine reproductive characteristics. In all cases (survival, number of broods, interval between broods, prereproductive period, reproductive period, post reproductive period, cysts per female and nauplii per female) better data were found at salinities upper 80 gL^{-1}. These results provide additional data to understand the adaptation patterns from each *Artemia* population and make the possibility to have better culture systems either in natural habitats or laboratory conditions to obtain cyst or biomass to aquaculture projects or university researches.

Key words: *Artemia franciscana*, reproductive characteristics, Yucatan peninsula strains, salinity culture.

RESUMEN

El crustáceo *Artemi*a puede sobrevivir en hábitats que presentan grandes cambios en la condición de salinidad (10 gL^{-1} a 340 gL^{-1}), de salinidad lo que puede modificar sus características reproductivas de las diferentes especies de *Artemi*a o diferentes poblaciones. Es por eso que este estudio se realiza con cuatro poblaciones de la península de Yucatán (CAN, CEL, RSAL y CRIS), tomando 0.5 g de quistes de cada población y así los nauplios eclosionados de ellos se colocaron en recipientes de plástico de 200 L, con 160 L de agua de mar (40, 60, 80, 100 y 120 gL^{-1}). Los organismos fueron alimentados con las microalgas *Tetraselmis* sp. y *Pinnularia* sp. hasta que los organismos alcanzaran el estadio pre adulto. Quince parejas (una hembra/2 machos) fueron emparentadas para determinar sus caracter´siticas reproductivas. En todos los casos (supervivencia, número de puestas, intervalo entre puestas, periodo pre, reproductivo y postreproductivo, quistes por hembra y nauplios por hembra) los datos fueron mejores a la salinidad de 80 gL^{-1}. Estos resultados proveen de información valiosa para entender los

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patrones de adaptación que presenta cada una de las poblaciones de *Artemia* y pueda hacerse realidad de obtener mejores cultivos, ya sea a nivel laboratorio o en hábitats naturales para obtener, según sea el caso, quistes o biomasa para los diferentes proyectos de acuicultura o para las investigaciones en las universidades.

Palabras clave: *Artemia franciscana*, características reproductivas, poblaciones de Yucatán, salinidad de cultivo.

INTRODUCTION

The genus *Artemia* comprises a complex of sibling species and super species defined by a criterion of reproductive isolation (Browne and Bowen 1991). A group named "New World" species is composed of *Artemia franciscana* Kellogg 1906 (North, Central and South America), *Artemia persimilis* Piccinelli and Prosdocimi 1968 (Argentina) and *Artemia monica* Verrill 1869 (USA). Another group named "Old World" species is represented by *Artemia salina* (Linnaeus 1758) (Mediterranean basis), *Artemia urmiana* Günther 1899 (Lake Urmia, Iran), *Artemia sinica* Cai 1989; and subspecie *Artemia sinica sinica* Cai 1989 (China); *Artemia tibetiana* Abatzopoulos et al. 1998; and subspecie *Artemia sinica tibetiana* (Tibet`s high Plateau), *Artemia* sp. Leach 1819 and parthenogenetic population(s) of *Artemia* Abatzopoulos et al. 2002.

These brine shrimp organisms are largely distributed in inland and coastal hypersaline body waters (Triantaphyllidis *et al.*, 1998, Castro *et al.*, 2000, Van Stappen 2002, El-Bermawi *et al.*, 2004). *Artemia* may inhabit chloride, sulphate or carbonate waters and combinations of more than two anions (Bowen *et al.*, 1985, Lenz *et al.*, 1987). *Artemia* are among a few organisms which adapted to survive in very diverse living conditions, including salinities as low as 10 gL^{-1} concentration (Abatzopoulos *et al.*, 2006a; Abatzopoulos et al. 2006b) and as high as 340 gL^{-1} salinity (Post and Youssef 1977).

There are some information on survival and reproductive characteristics of some bisexual and parthenogenetic *Artemia* strains (Vanhaecke et al. 1984; Wear and Haslett 1986; Browne et al. 1984; Browne y Bowen 1991; Browne y Wanigasekera 2000; Triantaphyllidis et al. 1995; 1997a,b Baxevanis et al. 2004; El-Bermawi et al. 2004; Abatzopoulos et al. 2003, 2006b; Agh et al. 2008) cultivated in different salinities. In Mexico there are some studies about these topics (Castro *et al*., 2009; Castro et al. 2010; Castro et al. 2011; Castro et al. 2013).

That's why the mean goal of this study was to determine the effect of salinity in survival and reproductive characteristics of four *Artemia* strains from Yucatan peninsula, cultured in laboratory at five salinities and thereby providing additional data to understand their adaptation patterns and its possibility to a better culture system tu use the biomass or cysts production in natural habitat or laboratory aquaculture projects.

MATERIAL AND METHODS

Strains used in the experiment

This study was conducted in Live Food Production Laboratory at Autonoma Metropolitana-Xochimilco University, Mexico. The cysts of four *Artemia franciscana* strains (Table 1, Fig.1) from Yucatán peninsula coastal zone were storage in -10ºC cooler to mantain the dehydrated process until 0.5 g for each strain were hatched under 40 gL^{-1} of salinity, pH 8-10; 25º$\pm$2ºC and constant illumination and air supply (Castro et al. 2003).

Culture system

The nauplii hatched were siphoned into separated beakers and transferred in 200 L plastic tanks with 160 L of salt water at different salinity concentration (40, 60, 80, 100 and 120 gL^{-1}). Density of *Artemia* nauplii was adjusted to one organism 100 mL^{-1}. The animals were feed *ad libitum* with 50 mL of rice bran (300 g $4L^{-1}$ of 90 gL^{-1} saline water), and 2 L of *Tetraselmis suecica* and 2 L of *Pinnularia sp*. (500,000 cel mL^{-1}).

Reproduction characteristics

Before we can saw mating, males and females were separated in 4L plastic beakers attained

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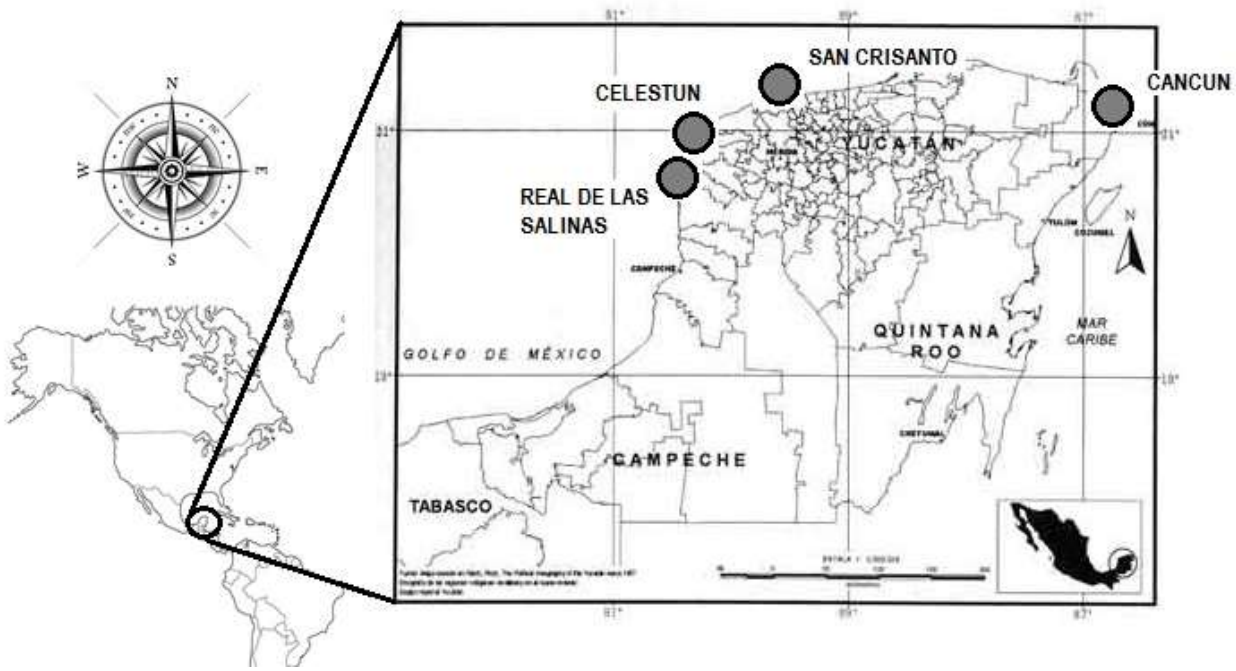

Fig. 1. Geographical location of *Artemia franciscana* Yucatan peninsula coast, Mexico strains habitat.

Table 1. List of Yucatan peninsula Mexican *Artemia* strains studied, abbreviation used and geographical location.

Site	State	Abbreviation	Geographical location
Cancún	Quinatana Roo	CAN	21°10` N; 86°47` W
San Crisanto	Yucatán	CRIS	21º 21` N; 89º 07`W
Celestún	Yucatán	CEL	20º 52` N; 90º 23`W
Real de las Salinas	Campeche	RSAL	20°02` N; 90°14` W

maturity, then 15 pairs of coupling bisexual *Artemia franciscana* (1 female and two males) were made from each strain and each salinity transferred into separated 200 mL beakers in order to study their life cycle characteristics. The dead males were immediately replaced with actively swimming males during the experiment according to Agh et al. (2008). The beakers were checked every day for presence of nauplii or cysts, which were counted and recorded separately to saw significant differences ($P<0.05$) between strains. Also reproductive and life span characteristics (number of broods per female, intervals between broods, total nauplii produced per female, total cysts produced per female, pre-reproductive, reproductive and post-reproductive period) were determined for each Mexican Yucatan peninsula strain according to Browne et al. (1984) and Agh et al. (2008).

Survival

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Survival was determined at the end of experiment culture. The results (expressed as percentages) were transformed with the formula:

$$\sqrt{\left(\frac{X\%}{100}\right)+0.5}$$

Statistical analysis

A data base was created with the software Microsoft Excel 2010 (Microsoft Corp., Washington, USA). Stem and leaf displays and Box Plot were performed to ensure that the assumption of normality was being met for each data set. A descriptive statistical analysis was made to obtained mean values and standard deviation for all reproductive characteristics variables. The reproductive characteristics data were transformed with the formula:

$$\sqrt{X+0.5}$$

Two-way analyses of variance (ANOVA) were used too, to determine if there were significant differences (Tatsuoka, 1970; Kachigan, 1991). The least Significant Differences (LSD) pairwise comparison Tukey method ($P<0.05$) was used to compare pairs of samples means after having generated ANOVAs for all characters studied. Type classifications were based on population grouped according their specific salinity cultured medium (Sokal and Rohlf, 1981; Kachigan, 1991). The SYSTAT 13 (Systat Software Inc., California USA) software package was used for statistical analysis.

RESULTS

Survival

The organisms for all populations, cultured in 40 gL^{-1} of salinity, die after seven culture days; they do not reach the juvenile stage. Records of the survival after 21 days of experiment indicated that the survival increase when increase the salinity concentration. The survival ranges were: 48-51% at 60 gL^{-1} salinity; 61-62% at 80 gL^{-1} salinity; 76-78% at 100 gL^{-1} salinity and 84-85% to 120 gL^{-1} salinity concentrations. The survival values were shown at Table 2.

All strains did not shown significant differences at same salinity culture test. The two ways ANOVA test did not show significant differences at strain and interaction between strain/salinity test variables because only provides the 0.012% and 0.199% of significance. The salinity variable show significant differences and provides the 99.78% of that.

Number of broods

The mean values were shown in Table 3. Number of broods increase with salinity. At 60 gL^{-1} shown six broods; at 80 gL^{-1} salinity test shown a 7-9 range; at 100 gL^{-1} salinity test have a 9-10 range and for 120 gL^{-1} salinity culture increase to 11-12 range. The two-way ANOVA analysis shows that salinity factor variable show significant differences between culture tests with 96% of significance.

Interval between broods

The mean values were shown in Table 4. The interval range is 2-3 days in all salinity tests. This variable did not change in strain, salinity and interaction variable.

Nauplii per female

The mean values were shown in Table 5. Nauplii produced per females range at different salinity tests were: at 60 gL^{-1} 41-46 nauplii/female; at 80 gL^{-1} 44-48 nauplii/female; at 100 gL^{-1} 49-52 nauplii/female and for 120 gL^{-1} salinity culture test with 53-57 nauplii/female. The two-way ANOVA test showed significant differences between strains, salinity tests and interaction between strain and salinity. The contribution to significance in percentage values were: for strain 11.12%; for salinity test 32.52%; and interaction between this two factors was 56.34%.

Cysts per female

The mean values were shown in Table 6. Culture salinity test of 60 and 80 gL^{-1} concentration

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Table 2. Mean (±S.D.) survival values of Yucatan peninsula *A. franciscana* strains.

Strains	Salinity cultures tests (gL^{-1})			
	60	80	100	120
Cancun	51.13^{a} ±6.07	61.70^{b} ±4.91	78.97^{c} ±4.71	84.17^{d} ±2.88
Crisanto	48.70^{a} ±5.82	62.97^{b} ±3.76	77.37^{c} ±4.96	85.27^{d} ±3.28
Celestun	49.03^{a} ±5.56	62.97^{b} ±4.65	77.67^{c} ±4.38	84.97^{d} ±3.26
Real de las Salinas	50.53^{a} ±5.73	62.77^{b} ±4.94	76.87^{c} ±5.18	85.10^{d} ±3.20

Same letter in column did not shown significant differences (P<0.05).
Different letters in a row, show significant differences between them (P<0.05).

Table 3. Number of broods mean values (± S.D.) of Yucatan peninsula *A. franciscana* strains.

Strains	Salinity cultures tests (gL^{-1})			
	60	80	100	120
Cancun	$6.74^{a,c,d}$ ±1.39	$8.30^{a,b,d}$ ±1.15	9.44^{c} ±0.88	$11.28^{c,d}$ ±1.21
Crisanto	$6.63^{b,c,d,f,g,h,I,k,l}$ ±0.75	$9.11^{a,d,e,h,i,j,l}$ ±1.49	$9.82^{a,b,e,k}$ ±1.34	$11.34^{a,b,c,e,f,l}$ ±2.10
Celestun	$6.56^{b,c,d,e,g,h}$ ±0.89	$8.76^{a,d,e,f,h}$ ±1.55	$10.01^{a,b,g}$ ±2.03	$10.86^{a,b,h}$ ±1.86
Real de las Salinas	$6.43^{b,c,d,f,g,h,j,k,l,m,n,o}$ ±1.63	$7.84^{c,d,g,h,k,l,m,n,o}$ ±2.45	$9.51^{a,e,i,n}$ ±1.76	$12.20^{a,b,c,d,e,f,g,i,j,k,l,n,o}$ ±2.61

Same letter, in row and column, showed significant differences between strains (P<0.05).

Table 4. Intervals between broods mean values (± S.D.) of Yucatan peninsula *A. franciscana* strains.

Strains	Salinity cultures tests (gL^{-1})			
	60	80	100	120
Cancun	2.36 ±0.95	2.33 ±1.04	2.23 ±0.87	2.36 ±0.83
Crisanto	2.34 ±0.71	2.75 ±0.69	2.53 ±0.80	2.37 ±0.70
Celestun	2.44 ±0.87	2.44 ±0.72	2.54 ±0.83	2.48 ±0.16
Real de las Salinas	2.65 ±0.70	2.54 ±0.69	2.12 ±0.74	2.48 ±0.78

did not shown cysts/female production. All strains began to produce cysts at 100 gL^{-1} salinity culture tests with 53-60 cysts per female; and 52 to 60 cysts range at 120 gL^{-1} salinity culture tests. The two-way ANOVA test did not show significant difference by strain factor and not for salinity and interaction (strain/salinity) factor, which shown significant differences. Salinity factor contribute with the 99.87% of the significance.

Pre-reproductive period

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Table 5. Mean values of produced nauplii per female (± S.D.) of Yucatan peninsula *A. franciscana* strains.

Strains	Salinity cultures tests (gL^{-1})			
	60	80	100	120
Cancun	$45.86^{a,d}$ ±10.86	$45.98^{b,d}$ ±9.84	52.73^{c} ±4.90	57.76^{d} ±10.23
Crisanto	$43.07^{c,d,h,i,k,l}$ ±4.79	$46.10^{d,h}$ ±7.75	$52.97^{e,j,k}$ ±7.60	$53.02^{e,l}$ ±7.35
Celestun	$41.61^{c,d,e,g,h}$ ±9.71	$48.93^{d,f,h}$ ±11.92	50.57^{g} ±7.08	$57.41^{a,b,h}$ ±9.25
Real de las Salinas	$43.20^{c,d,g,h,k,l,m}$ ±10.63	$44.38^{c,d,h,k,l,m}$ ±9.86	49.55^{e} ±8.19	$56.94^{a,b,e,f,i,j,m}$ ±7.36

Same letter, in row and column, showed significant differences between strains (P<0.05).

Table 6. Mean values of produced cysts per female (± S.D.) of Yucatan peninsula *A. franciscana* strains.

Strains	Salinity cultures tests (gL^{-1})			
	60	80	100	120
Cancun	n.d	n.d.	60.03^{a} ±5.59	54.71^{b} ±3.51
Crisanto	n.d.	n.d.	$57.46^{a,b,c,e}$ ±7.71	$54.02^{b,d,e,f}$ ±5.77
Celestun	n.d.	n.d.	$57.90^{a,b,c}$ ±6.17	$52.80^{b,d}$ ±5.58
Real de las Salinas	n.d.	n.d.	$53.44^{b,d,f}$ ±6.94	$60.02^{a,c,e}$ ±5.55

Same letter, in row and column, did not show significant differences between strains (P<0.05).
n.d. = no data.

Table 7. Pre-reproductive period mean values (days) (± S.D.) of Yucatan peninsula *A. franciscana* strains.

Strains	Salinity cultures tests (gL^{-1})			
	60	80	100	120
Cancun	$11.23^{a,c,d}$ ±2.31	13.06^{b} ±2.23	13.79^{c} ±2.73	14.82^{d} ±1.69
Crisanto	$10.28^{b,c,d,f,g,h,k,l}$ ±2.59	$12.22^{d,h,l}$ ±3.08	$12.78^{i,k}$ ±1.96	$15.24^{a,e,f,j,k,l}$ ±1.64
Celestun	$10.39^{b,c,d,e,g,h}$ ±3.46	$12.60^{d,e}$ ±2.45	$13.41^{a,e,f}$ ±1.95	$14.57^{a,g,h}$ ±1.24
Real de las Salinas	$11.63^{c,d,h,l,m}$ ±2.46	$11.97^{d,h,l,m}$ ±2.40	$13.45^{a,e,i}$ ±2.17	$14.65^{a,e,i,j,m}$ ±1.98

Same letter, in row and column, showed significant differences between strains (P<0.05).

The mean values were shown in Table 7. The ranges of pre-reproductive periods were: 10-11 days, at 60 gL^{-1} salinity culture test; 11-13 days, at 80 gL^{-1} salinity concentration; 12-13 days at 100 gL^{-1} and 14-15 days period, at 120 gL^{-1}salinity culture test. The two-way ANOVA test show significant differences by strains, salinity and interaction (strain/salinity) factors. The percentage contribution

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to significance value was by strain 11.03%; by salinity culture test 69.15% and by interaction 19.80%.

Reproductive period

The mean values were shown in Table 8. The ranges of reproductive periods were: 31-34 days, at 60 gL^{-1} salinity culture test; 32-37 days, at 80 gL^{-1} salinity concentration; 39-40 days at 100 gL^{-1} and 42-45 days period, at 120 gL^{-1}salinity culture test. The two-way ANOVA test did not show significant differences by strains; but salinity culture tests and interaction (strain/salinity) factors showed significant differences. The percentage contribution to significance value was salinity culture test of 92.28% and the interaction only with 7.50%.

Post-reproductive period

The mean values were shown in Table 9. The ranges of post-reproductive periods were: 5-6 days, at 60 gL^{-1} salinity culture test; 6-7 days, at 80 gL^{-1} salinity concentration; 7-8 days at 100 gL^{-1} and 9 days period, at 120 gL^{-1}salinity culture test. The two-way ANOVA test did not show significant differences by strains and interaction (strain/salinity) factors, but salinity culture tests show significant differences. The percentage contribution to significance value for salinity culture test was 95.70%.

DISCUSION

Survival

The osmoregulatory capacity of *Artemia* in different salt concentration habitat allows surviving, growing and reproducing in these conditions, with few some other organisms like microalgae, bacteria and some stage of insects who respond adequately to the stress of the ions dissolved in the medium,

Table 8. Reproductive period mean values (days) (± S.D.) of Yucatan peninsula *A. franciscana* strains.

Strains	Salinity cultures tests (gL^{-1})			
	60	80	100	120
Cancun	$11.23^{a,d}$ ±2.31	13.06^{b} ±2.23	13.79^{c} ±2.73	14.82^{d} ±1.69
Crisanto	$10.28^{b,c,d,g,h,i}$ ±2.59	$12.22^{d,h,j}$ ±3.08	$12.78^{a,e,f}$ ±1.96	$15.24^{a,b,e,f}$ ±1.64
Celestun	$10.39^{c,d,g,h}$ ±3.46	$12.60^{c,d,f,g,h}$ ±2.45	$13.41^{a,e,g}$ ±1.95	$14.57^{a,b,c,h}$ ±1.24
Real de las Salinas	$11.63^{c,d,g,h,k,l}$ ±2.46	$11.97^{h,i,l}$ ±2.40	$13.45^{e,f,h,i,k}$ ±2.17	$14.65^{a,b,e,f,i,j,l}$ ±1.98

Same letter, in row and column, showed significant differences between strains (P<0.05).

Table 9. Post-reproductive period mean values (days) (± S.D.) of Yucatan peninsula *A. franciscana* strains.

Strains	Salinity cultures tests (gL^{-1})			
	60	80	100	120
Cancun	$5.28^{a,c,d}$ ±0.84	$6.82^{a,b,d}$ ±1.28	7.77^{c} ±1.37	9.28^{d} ±1.24
Crisanto	$5.77^{c,d,f,g,h,i,j,k}$ ±1.43	$6.77^{a,d,g,h,j}$ ±1.47	$8.25^{a,e,i}$ ±1.82	$9.30^{a,b,e,f,j}$ ±1.60
Celestun	$5.44^{c,d,e,g,h}$ ±1.76	$7.31^{a,d,e,f,h}$ ±1.88	$8.75^{a,g}$ ±2.67	$9.59^{a,b,c,h}$ ±2.52
Real de las Salinas	$6.21^{c,d,g,h,i,j,l,m}$ ±1.34	$7.44^{a,d,e,h,j,k,m}$ ±1.63	$8.03^{a,e,k,l}$ ±2.36	$9.54^{a,b,c,e,f,k,m}$ ±2.01

Same letter, in row and column, showed significant differences between strains (P<0.05).

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and osmotic pressure of the internal fluids. *Artemia* nauplii presents a structure which is responsible for carrying out the process of osmoregulation, the neck salt gland and in adult stage the gut epithelium (Croghan 1958b; Plattner 1955) and meta - epipoditos in branchial segments (Copeland 1966; Croghan 1958a). This ability allows *Artemia* to live, grow and reproduce in a range of salinity <35 gL^{-1} to >210 gL^{-1} (Copeland 1967).

The Mexican of Yucatan peninsula strains culture in different salinities allows that below 60 gL^{-1} and above 120 gL^{-1}, the organisms die at metanuapliar stage, due to osmoregulatory mechanisms is affected when the nauplii were inoculated directly at this salinity concentration and is functional in a range of 60-120 gL^{-1} and therefore we can assume that length differences between Mexican strains is not due their habitat origin, butt is triggered by salinity variable. In contrast, Sayg (2004) suggests that these differences can be considered as local biotope response and not only salinity intrapopulation response, like ploidy level strain, larval energy content. Other authors such as Chapman (1968); Metalli and Ballardin (1972); Vanhaecke and Sorgeloos (1989), indicates that genetic variability may induce strain damping with respect extreme conditions such as salinity. Vanhaecke et al. (1984) also found low survival at 35 gL^{-1} and increases in salinities upper 90 gL^{-1}. Post and Youssef (1977) indicate that *Artemia* culture at salinities <45 gL^{-1} decreases survival; Hammer and Hurlbert (1992) observed that juveniles of different *Artemia* species and strains grow slowly and adults die at <38 gL^{-1} salinity. However, El- Bermawi et al. (2004) found that Egyptian *Artemia* have a survival of 60% at salinity of 35 gL^{-1}.

Comparing data with other species of *Artemia* genus like *A. salina*, *A. sinica*, *A. persimilis* and some parthenogenetic population(s) of *Artemia* (Browne and Wanigasekera (2000) shown 0-24% survival in culture test at 60 gL^{-1}. Van Stappen et al. (2003) who studied *A. tibetiana* found only 39% survival at 35 gL^{-1}. Sayg (2004), who studied parthenogenetic population(s) of *Artemia* from Turkey and Greece, found survival of 15% at salinities below 80 gL^{-1}; Agh et al. (2008) and Abatzopoulos et al. (2006a,b) obtained 0 % survival with *A. urmiana* at 50 gL^{-1} salinity culture test. With respect American Continent *Artemia* species Medina et al. (2007), found with *A. persimilis* survival rates of 5.3% only at 30 gL^{-1} of salinity. For all these studies the salinity range of 80-120 gL^{-1} were considered the most appropriate to inoculate the hatching nauplii, except with the specie *A. tibetiana*.

These changes may be different between *Artemia* species or strains from the same specie but they are separated by geographical or chemical barriers (Cole and Browne 1967).

With respect to inoculate the Mexican naplius stage at salinities upper 120 gL^{-1} culture, Yucatan peninsula populations shown 100% mortality because this stage can activate the proper enzymes to avoid the osmoregulatory mechanism (Clegg and Trotman 2002). Also studies of Dana y Lenz (1986), shown if culture salinity is upper 179 gL^{-1} survival decrease below 20% and the osmoregulatory apparatus is damage not only for ion concentration, but also by frequency and time duration at that salinity concentration in their own habitat. *A. salina* cultivated in a range of 150-200 gL^{-1} salinity shown 100% mortality; with *A. urmiana*, 100% mortality was shown when they were inoculated to 200 gL^{-1} salinity culture medium (Agh et al. 2008; Abatzopoulos et al. 2006b).

In summary, the salinity concentrations <60 gL^{-1} and >120 gL^{-1}, affect the survival of Mexican *Artemia* Yucatan peninsula populations, also another *Artemia* species cultivated at laboratory conditions like shown the same condition: *A. urmiana*, *A. persimilis*, *A. tibetiana.* It´s possible maintained *Artemia* cultures at laboratory if salinity increase makes gradually (10 gL^{-1} every week) to allow the enzymatic activity established in osmoregulatory mechanism in the culture organisms (Post and Youssef 1977; Wear et al. 1986; Triantaphyllidis et al. 1995; Van Stappen 2002; Agh et al. 2008) like in natural habitat. Tackaert and Sorgeloos (1991) mentioned that genetically imprinted factor exist to respond salinity changes in each *Artemia* specie or strain and it´s functional better at 100-180 gL^{-1} salinity concentration. This can saw in Mexican Yucatan peninsula strains, being the salinity variable that shows 80% of significance variability. This information allows

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making better laboratory culture management of this crustacean when the salinity, temperature and food variables can be controlled (Wear and Haslett 1987).

Reproductive characteristics

The reproductive characteristics variables of Mexican Yucatan peninsula strains were influenced principally for salinity factor and only nauplii per female production for the interaction of strain and salinity culture test factors. Browne (1982) and Browne et al. (1984) mentioned that type of food and their concentration can be modified the reproductive response of *Artemia* species or strains, but in this study these two variables be maintained constant during all experiment long.

In all *A. franciscana* strains from Yucatan peninsula shown that values increment with upper salinity concentration. The oviparity only show at salinities 100 to 120 gL^{-1} concentration, although always be nauplii production; the quantity of cyst did not changes at 100 or 120 gL-1 salinity concentration and nauplii production increase twelve more nauplii per female. Intervals between broods did not change with salinity concentration. The pre-reproductive period increase four days with salinity, ten days for reproductive period and four days for post-reproductive period. The increase of number of days at reproductive period allows an increase of number of broods per female in all populations. Authors like Bowen et al. (1988) and Browne y Wanigasekera (2000) mentioned that optimal culture salinity was in which the reproductive period of different *Artemia* strains was longer day's duration.

With respect number of broods per female, Mexican peninsula *Artemia* strains presents the same variation (6-12 broods). Authors like Browne et al. (1984) mentioned in their study 4-14 broods per female at 90 gL^{-1} salinity; Amat et al. (2004) reports six broods per female at 70-80 gL^{-1} salinity tests. Different results were shown with Baxevanis et al. (2004), who reported only two broods per female at 120 gL^{-1} salinity. Studies with other *Artemia* species, showed 4-7 broods per female at 90 gL^{-1} salinity with *A. tunisiana* (Browne et al. (1984); with *A. urmiana*, Agh et al. (2008) showed six brood per female at 50 gL^{-1} salinity concentration test and only one brood per female at 150 gL^{-1} salinity. For parthenogenetic population(s) of *Artemia* Browne et al. (1984) mentioned 8-19 broods per female at 90 gL^{-1} salinity culture test.

With respect the intervals between broods, Mexican peninsula Yucatan *Artemia* strains did not modified the quantity of days (2 days) unlike other studies like Baxevanis et al. (2004) who reported four days at 120 gL^{-1} salinity culture test. With other *Artemia* species, the values changes 4-5 days at 75-175 gL^{-1} salinity with *A. urmiana* (Agh et al. 2008); the parthenogenetic population(s) of *Artemia* obtained seven days at 120 gL^{-1} salinity; although Abatzopoulos et al. (2003) and Baxevanis et al. (2004) obtained only two days for same populations, but they found and increase of five days with 200 gL-1 salinity culture test. Triantaphyllidis et al. (1995); Van Stappen (2002) and Van Stappen et al. (2003) mentioned that data variability in this reproductive characteristic is the salinity response for each species or *Artemia* strains to increase or decrease of salinity concentration. Browne et al. (1984) mentioned that *Artemia* populations which have longer intervals between broods allow better health recover female organisms between each cyst or nauplii reproductive event. Although Mexican Yucatan *Artemia* strains have only two day between broods, number of brood increase with salinity thereby allowing more nauplii or cysts production.

With respect nauplii per female production, Mexican Yucatan *Artemia* strains, presents great variability like other studies like Browne et al. (1984) y Baxevanis et al. (2004) with same *A. franciscana* specie; Abatzopoulos et al. (2003) with parthenogenetic population(s) of *Artemia*; and Agh et al. (2008) with *A. urmiana* specie.

With regard to cysts per female production, Barata et al. (1996) mentioned that this type of reproduction in this organism was present when the high salt concentration levels were maintained during longest culture periods tests. Baxevanis et al. (2004) found this same condition with *A. franciscana* specie; Abatzopoulos et al. (2003) and Arashkevich et al. (2009) with parthenogenetic population(s) of *Artemia;* and Agh et al. (2008) with *A. urmiana* specie. This *Artemia* encystment process

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not only respond to salt concentration medium and the period who organisms were maintained in that salinity, but also at ion medium salt composition (Jennings and Whitaker 1941); Jacobi and Baas-Becking (1933) probe that encystment process in animals did not shown even if salinity is upper 80 gL^{-1} salinity, but there must be the appropriate salt ion for each *Artemia* strain.

In summary, the knowledge of this reproductive characteristics allow a better culture *Artemia* management, also at laboratory or natural habitat culture system to obtain better nauplii or cysts productions and use it to aquaculture industry.

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