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Utilization of Brackish Water Residues from Desalination Units in the Palestinian Region for Marine Fish Farming

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Abstract:

The utilization of brackish water residues from desalination units for mariculture in Palestine could represent an environmental friendly alternative of disposing brine water which could have an adverse effect on wildlife. Brackish water residues from desalination units is a new local resource that can be used for fish mariculture to introduce a new cheap source for proteins in Palestine.

These studies attempted to assess the potential use of brackish water residues from Jericho desalinateion units in the Palestinian region for fish Mariculture. In the course of attempting Mariculture in inland brackish water, two experiments were conducted in Aquaculture research laboratory, Al-Quds University, Jerusalem, Palestine. In the first experiment, three juvenile marine fish species (Gilt-head bream *S. aurata*, European sea bass *D. labrax*, and red drum *S. ocellatus*) average weights of 4.31 g,0.77 g and 1.24 g per fish respectively, were acclimated and reared in brine brackish water residues collected from Jericho desalination units. Fishes were reared in water of 6.5 ‰ and 11 ‰ salinity for 3-7 months (20 fish per aquaria). Fish were fed by rich protein diet 56 %. Brine brackish water contained high levels of Cl^{-1} (3369 mg L^{-1}), Na^{+1} (3735 mg L^{-1}), K^{+1} (300 mg L^{-1}), SO_4^{-2} (716 mg L^{-1}) with the divalent ions Mg^{+2} (57.3 mgL^{-1}) and Ca^{+2} (276 mg L^{-1}). The experimental well showed more than the maximum allowable concentration of Cr (14.94 μg L^{-1}), Ag (5.31 μg L^{-1}) and Mn (27.88 μg L^{-1}) for water quality of fisheries use. The sea bass reared in saline water of 6.5 ‰ showed an acceptable growth performance parameters and reached a percentage weight gain (% WG) of 6345.23 % and a survival rate of 77.5 % compared to control groups at 11 ‰ salinity that reached at the same period a (% WG) of 6543.78 % and a survival rate of 82.5 % after 30 weeks. Sea bream reached a (%

WG) of 241.63 % and 772.44 % after 15 weeks at 6.5 ‰ and 11 ‰, respectively. while red drum juveniles reached a (% WG) of 2661.60 % and 2673.92 % after 15 weeks at 6.5 ‰ and 11 ‰, respectively. Survival rate was only ≤ 5 % at both salinities for the two species. In a further study sea bass fingerlings with an average weight of 20.5 g were reared in brackish water of 6.5 ‰ salinity for 7 weeks (4 fish per aquaria) and were fed superior fish meal with fish oil. They received diets of 2.1 %, 3.0 %, and 4.0 % of body weight. Sea bass fingerlings which received diets of 2.1 %, had the highest FCE (0.82) and PER (1.46) with the lowest FCR (1.22). These results confirm that the most suitable fish for cultivation utilizing brackish water from Jericho desalination units with salinity of 6.5 ‰ is sea bass *D. labrax*, while the other two species need some modification to acclimatize to this water.

The second experiment had aimed to predict an appropriate feeding rate for the most suitable species farming. The best feed % of body weight for optimum growth of sea bass at this salinity was found to be 2.1 % after 7 weeks. Brackish water from Jericho desalination units were suitable for cultivation of these species, but may need some modification as adding salts to fish diet or water and reducing toxicity of some high trace metals present.

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Chapter One

Introduction

1.1 Brackish Water

Brackish water is water with salinity between (0.5-30 g L^{-1}). Of all the Earth's water, 94 % is salt water from the oceans and 6 % is fresh. Of the latter, 72 % is underground and 27 % is in glaciers (Buros, 2000). In Palestine brackish water is found naturally, in the Jordan River Valley, West Bank and in different parts of the Gaza Strip. Water in the West Bank is derived from two sources, wells and springs, while the Gaza Strip is entirely dependent on wells (Table 1.1).

Table 1.1: Annual Available Water Quantity in the Palestinian Territory from Local Resources by Region, 2010 (adapted from refs. (PWA, 2011)).

Region	*Springs discharge (MCM)*	*Water pumped from Palestinian wells (MCM)*
West Bank	26.8	71.6
Gaza Strip	-	172.4*

*This includes the quantities pumped from the UNRWA wells.

In 2010, 123 MCM of the water used for agricultural came from wells (38 MCM/year in the West Bank and 85 MCM/year in the Gaza Strip) and the remaining 22.8 MCM/year came from springs in the West Bank (PWA, 2011).

Agricultural wells are considered as the main source of water for agricultural uses in conjunction with agricultural springs. Agricultural wells' production formed 39 % of the total West Bank resources (38 MCM/year) (Figure 1.1), while brackish water formed 26 % of the total Gaza resources (46 MCM/year) (PWA, 2011) as in Figure 1.2.

Apart from the Brackish wells there are 297 springs and seeps in the West Bank with 43 springs yielding more than 0.1 liter sec^{-1} (PWA, 2011). The average annual flow is around 26.8 MCM. Springs production formed 27 % of the local resources. This source of water has two main uses, domestic and agricultural depending on its quality. The amount of fresh water is 4 MCM (15 % of the total yield from springs), used mainly for domestic. The rest (22.8 MCM) is brackish water used for agriculture (85 % of the yield from springs). Nablus (6.1 MCM) and Jericho (17.3 MCM) formed 87 % of the total springs' production (PWA, 2011).

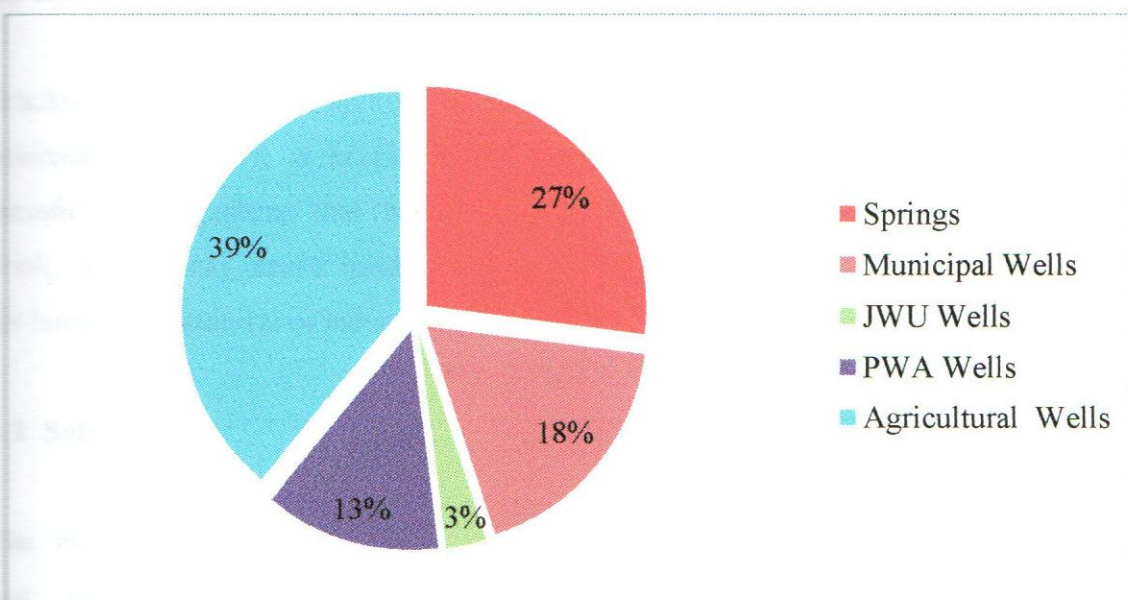

Figure 1.1: Local Water Resources in West Bank (PWA, 2011).

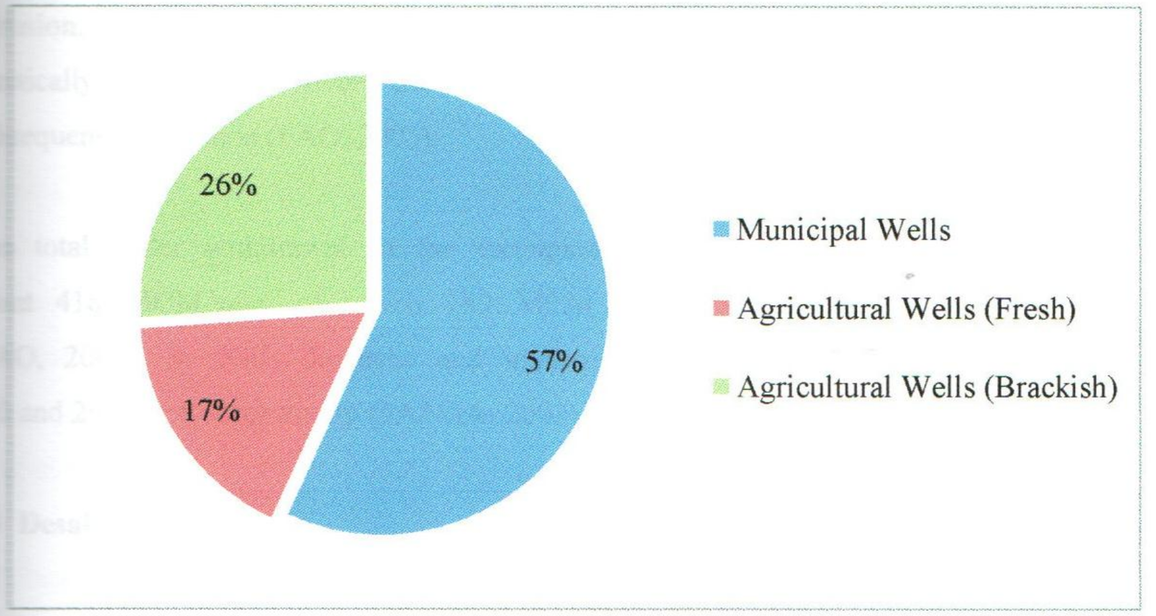

Figure 1.2: Local Water Resources in Gaza Strip (PWA, 2011).

Brackish water may result naturally from mixing of fresh water with seawater, and it may occur in brackish fossil aquifers. Brackish water can also resulted from man-made projects, certain human activities can produce brackish water or may increase the concentration of salts, in particular certain desalination units, brackish water with high salt content is considered as a primary waste product of the desalination process.

Brackish water needs appropriate management to prevent its damage to the environment; since it is hostile to the growth of most terrestrial plant species, and harmful the organisms that have not been adapted to it. It is also unpleasant to drink, and it may cause health problems. Brackish water is not considered suitable for human, agricultural or industrial use due to high salt content (Eubank, 1993).

1.2 Salinization

The major causes of salinization are geological factors, over-pumping of the wells and seawater intrusion. Salinization of the water from the shallow aquifer irrigation wells is increasing in the West Bank particularly in the Jordan Valley. In the Gaza Strip overexploitation of the aquifer has already resulted in seawater intrusion. The quality of the groundwater, particularly in the Gaza Strip has drastically deteriorated over the last twenty years due to over-pumping and subsequent salinization (FAO, 2005).

The total water withdrawal in the Occupied Palestinian Territory is estimated at about 418 MCM/year, of which 189 MCM or more than 45 % for agriculture (FAO, 2005). In 2005, domestic and industrial water withdrawal was estimated at 200 and 29 MCM, respectively (PASSIA, 2003).

1.3 Desalination

Desalination process is currently the fastest growing and the most promising technique for seawater and brackish water desalination. More than 15,000 industrial scale desalination plants had been installed worldwide, by the year 2002 (Wangnick, 2002). At present, world total desalination capacity is estimated as 10-30 MCM/day (Fell, 2003). The substantial cost decline of desalination process has contributed much to the rapidly growing success of desalination technology (Fell, 2003). Over the last decade, the operating cost for desalination of seawater has dropped from US$ 1.5 to US$ 0.5-0.8/m^3; the cost is around US$ 0.2-0.35/m^3 for brackish water (Baker, 2004; Semiat, 2000).

Desalination has been established as a reliable technique for removing salt from brackish water, thus making these water resources available. Desalination processes produce two resultant streams. One is the product stream, which has a low level of TDS, and the other is the brine (or reject) stream, which has a higher level of dissolved salts than either the feedwater or the product water. The brine must be disposed of in an environmentally acceptable manner (Spiegler & Laird, 1980).

Desalination water treatment facilities are used in Jericho and in the Jordan Valley region to produce fresh water from the brackish wells, which are used for different purposes. Currently there are three desalination units that had been already installed in Jericho.

The problem with desalination is disposing of big amount of brackish and brine water, which could have an adverse effect on wildlife if we dispose it in the environment (Girard, 2010). Desalination unit in Jericho produces two resultant streams. One is the fresh stream, which is 9 m^3 /10 m^3 feedwater (90 % of Feedwater volume), and the other is the brackish stream, which is 1 m^3 /10 m^3 feedwater (10 % of Feedwater volume), by time, this brackish water accumulates and form problem to the environment if does not dispose of in an acceptable manner. The possible desalination of brackish water existing in both the Gaza Strip and the West Bank is currently estimated at 90 MCM/year (FAO, 2005).

1.4 Brackish Water Desalination

Water desalination has positive impacts on the environment, such as increasing fresh water availability and recycling brackish water. However, it has negative impacts, such as brackish disposal of residues from the desalination process.

Two thirds of Historical Palestine are covered by desert, beneath this desert are large aquifers containing huge quantities of fossil, geothermal saline water. For the last 30 years this brackish water has been successfully used for irrigation of agricultural crops (e.g., tomatoes, melons, wheat, cotton, olives, etc.). Since previous investigations have shown the significant potential of the geothermal, brackish water for the successful culture of aquatic organisms (Appelbaum et al., 2008a).

Desalination techniques may be classified into three categories according to the process principle used:

- A process based on a physical change in state of the water - i.e. Distillation;
- The process uses membranes - i.e. RO; and,
- The process is acting on chemical bonds - i.e. Ion exchange.

It is a known fact that the Gaza aquifer and some potential sources from the eastern aquifer in the West Bank suffer from a high salinity rate. It is estimated that 53 MCM/year of brackish water in the West Bank from the al-Fashkah springs, and most of the Gaza aquifer, need to be desalinated (GTZ & WESC, 1995).

Parallel to the climate changes with its impact on the hydrologic cycle there will be increasing urbanization and a consequent raising demand for urban water supply, which may be partly answered by desalination of seawater and brackish groundwater (Dwiek & Hillel, 2007).

1.5 The Importance of Introducing Mariculture in Palestine

Almost the entire consumption of animal protein of the Palestinians comprises of chicken, mutton, and beef with fish playing only a minor role. The imbalanced consumption of animal protein, coupled with high stress levels, high blood pressure, and widespread tobacco smoking are known to be responsible for high cholesterol levels and increased risk of coronary heart disease in the PA. Indeed, a survey held by the Israel ministry of health has shown that Palestinians living in East Jerusalem have much higher coronary heart disease mortality than the Jewish community there (Kark et al., 2006). The increase of fish in the diet-mix would diversify the sources of animal protein and make a positive contribution to community health because of the favorable nutritional characteristics of fish compared to meat.

The composition of most fish falls in ranges of about 18-35 % total solids, 14-20 % protein, 0.2-20 % fat, and 1.0-1.8 % ash (Norman & Joseph, 1998). Nutritionally, fish proteins are highly digestible and at least as well as red meat with respect to content of essential amino acids. Fats of fish also are readily digestible and rich in unsaturated fatty acids. Fish are rich in vitamins as VA and VB, and the bones fish are an excellent source of calcium and phosphorus (Norman & Joseph, 1998).

introducing aquaculture to the Palestine Authority, particularly the West Bank; thus seems a good opportunity for many reasons: production of fresh fish for the local market, better production efficiency of fish protein and enhancement of fish quality; utilizing existing water bodies without prejudicing current uses of water for domestic or agricultural purposes. Furthermore introduction of a new economic activity could contribute to the socio-economic progress of the region. If we succeed in our experiment, we can introduce a very rich source of protein in the Palestinian diet, and decrease the percentage of protein deficiency diseases.

1.6 Brackish Water Residues from Desalination Units for Marine Fish Farming

Since, brackish water forms an important habitat for some unique animal species, so there are many fish that live in brackish water and would be best suited to a brackish habitat, for example seabass, gilthead seabream, red drum barramundi, and hybrid striped bass. So the main objective of this research proposal is the utilization of brackish water residues from desalination units such water waste for mari culture in Palestine.

Advantages of low salinity brackish water from desalination units for aquaculture (Appelbaum, 1997; Shmuel & Yacov, 2002):

- The large amount of accessible subsurface unpolluted brackish water is most suitable for marine fish culture.
- The cost of low salinity brackish water is lower than that of fresh water.
- Land in the brackish water and desalination units area is plentiful and cost less than in other regions.
- The free brackish water allows a high quality fish product for the customers compared to fresh water.

1.7 Brackish Waters in Jericho Region

Jericho city, is located in the Jordan Valley, north of the Dead Sea and west of the Jordan River. From 1967-1994 Jericho was occupied and administered by Israel.

العنوان: استخدام المياه المالحة الناتجة من وحدات تحلية المياه في المناطق الفلسطينية لتربية الأسماك البحرية.

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اشراف: د. معتز القطب

ملخص:

في سياق محاولة تربية الأسماك البحرية عن طريق الاستفادة من المياه المالحة الناتجة من وحدات تحلية المياه المالحة، تم أجراء هذا البحث في مختبر بحوث تربية الأحياء المائية، في جامعة القدس، القدس، فلسطين.

ثلاثة أنواع من الأسماك البحرية (الدنيس الشبوط، القاروص، والطبل الأحمر) حيث كان متوسط وزن الدنيس 4.31 غم, ومتوسط وزن القاروص 0.77 غم, ومتوسط وزن الطبل الأحمر 1.24 غم. تم تغذيتها بحمية غذائية غنية بالروتين تصل إلى 56٪، لمدة تتراوح بين 3 وأكثر من 7 شهور في نوعين من المياه المالحة:6.5 و 11 ‰ من مصدرين مختلفين.

وضِعت الأسماك البحرية في أحواض سعة كل منها ≈ 45 لتر في نظام مغلق. تم ضبط التغذية وفقا لوزن الأسماك، حيث يتم وزن الأسماك ويتم عدها لتحديد معدل الإعاشة.

كانت عملية وزن الأسماك فردية لجميع الأسماك في كل حوض بواسطة ميزان حساس دقته تصل إلى 0.01 غم.

كان متوسط وزن البداية لإصبعيات الدنيس 4.31 غم, وكانت نتائجها أفضل عند تربيتها في مياه ذات ملوحة 11 ‰، حيث أزداد وزنها تقريباً 772.45٪، في حين أن الزيادة كانت بنسبة 241.63٪ في المياه ذات الملوحة 6.5 ‰.

كان متوسط وزن البداية لسمك القاروص 0.77 غم, وصلت إلى زيادة في الوزن تصل إلى 6345.23٪, ونسبة الوفيات 22.5٪.في حين وصلت زيادة وزن مجموعات المراقبة في 11 ‰ الى 6543.78٪ و نسبة الوفيات 17.5٪.

في دراسة الطبل الأحمر مع معدل وزن 1.24 غم تم تربيتها في مياه ذات ملوحة 11 ‰ لمدة 15 أسبوع زاد وزنها 2673.92٪ ونسبة الوفيات 100٪ في حين أن الأسماك التي تم تربيتها في مياه ذات ملوحة 6.5 ‰ وصلت الزيادة في وزنها 2661.60٪ ونسبة الوفيات 97.5٪ خلال نفس الوقت.

في آخر دراسة قمنا بأجرائها على إصبعيات القاروص, لمعرفة أفضل نسبة غذائية, كان متوسط وزن السمك عند بدء التجربة 20.5 غم, تم تغذيتها بأغذية تتكون من لحم السمك وزيت السمك, وكانت غنية بالبروتين بنسبة 56٪, تم تربيتها في مياه ذات ملوحة 6.5 ‰ لمدة 7 أسابيع، حصلت الأسماك على وجبات غذائية مختلفة 2.1٪, 3.0٪, و 4.0٪ من وزن السمك, وكانت نتائج معامل التحول الغذائي 0.82, 0.59, و 0.42 على التوالي.

تبين نتائج الأبحاث المذكورة أعلاه بشكل قاطع إمكانية استخدام المياه المالحة من وحدات تحلية المياه لاستزراع الأسماك البحرية كبديل إضافي للزراعة البحرية التقليدية (مثل سمك المشط). وهذه النتائج ليست مستغربة نتيجة لخصائص الأسماك البحرية (واسعة المدى الملحي) حيث أنها في مراحل حياتها المبكرة تتواجد في بيئات مختلفة الملوحة.

هذه هي المرة الأولى على حد علمنا التي يتم فيها تجربة استخدام المياه المالحة الناتجة من وحدات تحلية المياه لتربية الأسماك البحرية في فلسطين. وهناك حاجة إلى أجراء تجارب إضافية وميدانية في البرك خارج المختبر للتحقق والتأكد من النتائج على نطاق واسع. بالإضافة إلى تدريب كادر على الاستزراع السمكي حيث أن خبرتنا في هذا المجال تكاد لا تذكر مقارنة مع الخبرات العالمية.

Chapter Five

5.1 Conclusions

This is the first time to our knowledge when where tested the growth rate of marine fish in brine waste brackish water from desalination units in Palestine. The results showed that the most suitable fish for cultivation utilizing brackish water from desalination units with salinity of 6.5 ‰ is sea bass (*D. labrax*), while the other two species need some modification to acclimatize to this water. The sea bass with an average weight of 0.77 g showed acceptable growth performance parameters and reached a % WG of 6345.23 % and a survival rate of 77.5 % compared to control groups at 11 ‰ that reached at the same time a % WG of 6543.78 % and a survival rate of 82.5 % after 30 weeks. On the other hand sea bream (*S. aurata*) and red drum (*S. ocellatus*) showed lower % WG and higher mortality rates. The red drum juveniles reached a % WG of 2661.6 % after 15 weeks but survival rate was only 5 % at 6.5 ‰, this could be contributed to several factors including osmolality changes and rate of fish adaptation, toxic effect of some high trace metals in our experimental water and optimal requirement of some necessary anions like chloride and calcium needed for optimal growth. The requirements for maximum weight gain determined in this study, when expressed as a dietary concentration, were similar to those determined for sea bass. However, the expression of requirements in manipulating formulations and feeding strategies is to meet economical purposes. Sea bass fingerlings which received diets of 2.1 % of body weight, had the highest FCE and PER. This confirms that the best feed % of body weight for optimum growth of sea bass is 2.1 % after 7 weeks. In summary, brackish water from desalination units could be suitable for marine fish cultivation, but may need some modification as adding salts to fish diet or water and reducing toxicity of some high trace metals present by a suitable method.

5.2 Recommendations

- First of all the work in aquaculture experiment need a lot of patience, accuracy, sincerity and commitment during the experiment because you are dealing with living organisms.

- To achieve fast growth rate, high survival rate, and get marketable fish size the environment should be ideal for marine fish.

- Further research is need to :-

  1. Utilization of brackish water from desalination units for marin fish farming to know more about the effect on aquaculture.

  2. Investigate the effect of adding salts that are deficient in low saline water sources into the diets of seabream and red drum to make this culture practice as more feasible.

  3. Farming other marine fish types.

  4. Focus on the influence of decrease feeding on growth rate of marine fish to lower production costs.

- The wastewater which was used during the experiment should be used for other activities such as agriculture, the wastewater from fish aquaculture could be used as fertilizer if we use suitable crops that tolerate the component of this type of water.

- More precise nutritional information required about marine fish farming. Nutritional information regarding aquaculture has increased significantly in recent years but is still incomplete.

- Aquaculture research is very expensive, so PA, Banks, other institution should support this type of economical research.

- Environmental Impact Assessment (EIA) studies are needed. Continuous monitoring of effluents and research on brackish water disposal are also required.