2003

Use of Date Pits as an Energy Source for Nile Tilapia, Oreochromis niloticus

Maitha Mohammed Sultan Al-Darmaki

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United Arab Emirates University
M.Sc. Program in Environmental Science
Deanship of Graduate Studies

Use of Date Figs As An Energy Source For Nile Tilapia,
Oreochromis niloticus

Submitted to the Dean of the Graduate Studies, United Arab Emirates University in Partial Fulfillment of the Requirements for the Degree of Master of Environmental Sciences

By
MAITHA MOHAMMED SOLIAN AL-DARMAKI
Bachelor in Science (Biology)

Supervised by

Prof. Abdel-Fattah M. El-Sayed and

Dr. Waleed Hamza

Professor of Aquaculture
Department of Arid - land Agriculture, College of Food System, U.A.E. University

Associate Professor of Marine Biology, Chairman of Biology Department, College of Science
U.A.E. University

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Table of Content:

Acknowledgement ........................................... I
Abstract .................................................... II
List of tables ................................................ IV
List of figures ............................................... VI
Introduction .................................................. 1

Literature Review ......................................... 4
Taxonomy of tilapia and most cultured species ........ 4
Nutrient Requirements of Tilapia ....................... 4
1. Protein and Amino Acid Requirements ............... 5
1.1. Essential Amino Acid Requirements ............... 9
1.2. Dietary Protein Sources ............................ 12
1.2.1. Fish Meal ........................................ 13
1.2.2. Animal by-products ............................. 14
1.2.3. a. Plant protein sources ....................... 16
1.2.3. b. Grain Legumes and plant protein .......... 19
1.2.3. c. Aquatic plants ................................ 20
1.2.4 Single Cell Protein (SCP) ....................... 21
2. Dietary Energy Requirements ....................... 22
2.1 Energy sources ....................................... 23
2.1.1. Lipids and Essential Fatty Acid Requirement 23
2.1.1. a. Essential Fatty Acid (EFA) ............... 23
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical analysis</td>
<td>57</td>
</tr>
<tr>
<td>Results</td>
<td>59</td>
</tr>
<tr>
<td>1. Experiment I:</td>
<td>59</td>
</tr>
<tr>
<td>2. Experiment II:</td>
<td>73</td>
</tr>
<tr>
<td>Discussion</td>
<td>81</td>
</tr>
<tr>
<td>References</td>
<td>89</td>
</tr>
<tr>
<td>Arabic Abstract</td>
<td>118</td>
</tr>
</tbody>
</table>
Acknowledgement

It is said, "Never settle for less than your dream. Somewhere, sometime, someday, somehow, you’ll find them". Thank you Allah by the names you are known and called. It is only by your grace, I have made it this far. Thank you.

I gratefully acknowledge all who have given me their time, effort, or advice. No matter how big or small it was, it all had made a difference. In particular, however, I am grateful, to my supervisors, professor Abdel Fattah El-Sayed and Dr. Waleed Hamza, who were excellent supervisors and guided me all though my work. I am especially aware of my debt also to Mr. Mamdouh Ibrahim who helped me in many ways in the practical part of the work, Mr. Adel Kawawy, who helped me in the chemical analysis, professor Mahmoud Al-Gandour and Dr. Mohammed Bin Jidi, who helped me in the statistical analysis. Finally, I would like to thank my family, friends and colleagues, for their different, but essential support.
Abstract
Abstract

The present study was conducted to evaluate date pits as an energy source of Nile tilapia fingerlings and adults, in two consecutive experiments. In the first experiment, five isocaloric (450 kcal/100g)-isonitrogenous (35% crude protein) diets containing of date pits as a replacement for wheat bran (energy source) 0, 25, 50, 75 and 100% levels were prepared. The diets were fed to duplicate groups of Nile tilapia, *Oreochromis niloticus* fingerlings and adults, with average initial weights of 10 and 50g, respectively twice a day, for 70 days. The culture system consisted of 70-L, fiberglass tanks connected together in a closed system. The results indicated that the inclusion of date pits in the diets of both sizes resulted in a significant retardation in growth performance and feed utilization efficiency of Nile tilapia. Body composition was not significantly affect by dietary treatment except for body lipid which was significantly decreased in adult fish fed 100% date pits. The results revealed also that fingerlings fish utilized date pits more efficiently than adult fish.

In the second experiment, 8 isocaloric (450 kcal/100g)-isonitrogenous (35% crude protein) containing 0, 25 and 50% date pits, 25 and 50% acid treated date pits, 25 and 50% date pits supplemented with exogenous enzyme and 50% acid treated date pits supplemented with enzymes. The diets were fed to Nile tilapia fingerlings (10g), twice a day for 88 days. The results indicated that the control diet produced better growth performance and feed efficiency ratio than date pits-based diets. Growth performance and feed efficiency were significantly retarded with the increase in date pits levels.

Protein and energy retention and body composition were not significantly affected by date pits levels. Acid treatment and enzyme supplementation did not improve date pits quality.
In conclusion, despite the retardation in the performance of fish fed date pits, the decrease in feed cost may compensate for this retardation. Therefore, about 25% raw date pits could be included in tilapia diets as a replacement of wheat bran.
List of Tables:

Table 1: World cultured tilapia production form 1995 to 2000 (FAO, 2002) 3
Table 2: Protein requirements of cultured tilapia 7
Table 3: List of essential amino acid in fish diets described by NRC (1981) 10
Table 4: Essential amino acid requirements of *O. mossambicus* and *O. niloticus* as a percent of dietary protein and diet (in parentheses) 11
Table 5: Major date palm producer in 2001 (FAO, 2002) 41
Table 6: Average composition of ripe date (Lambiote, 1983) 41
Table 7: Average chemical composition of date pits (FAO, 1999) 43
Table 8: Chemical composition of date pits used in the experiments 50
Table 9: Composition and proximate analysis of the test diets fed to Nile tilapia in the first experiment 52
Table 10: Composition and proximate analysis of test diets fed to Nile tilapia in the Second Experiment 53
Table 11: Growth rates, feed conversion efficiency and protein and energy retention of Nile tilapia fingerlings (10g) fed the test diets in experiment I for 70 days. Values in the same column with different letters are significantly different (P< 0.05): 60
Table 12: Analysis of variance of the results obtained in the first experiment: 61
Table 13: Body composition in a dry base weight of Nile tilapia fingerlings (10g) fed diets in experiment I. values in the same column with different letters are significantly different (P < 0.05): 65
Table 14: Growth rates, feed conversion efficiency and protein and energy retention 67
of Nile tilapia adults (50g) fed the test diets in experiment I for 70 days. Values in the same column with different letters are significantly different (P< 0.05):
Table 15: Body composition in a dry base weight of Nile tilapia adult (50g) fed diets in experiment I. Values in the same column with different letters are significantly different (P< 0.05)
Table 16: Growth rates, feed conversion and protein and energy retention of Nile tilapia fingerlings (10g) fed the test diets in experiment II. for 88 days. Values in the same column with different letters are significantly different (P< 0.05).
Table 17: Analysis of variance of the results obtained in the second experiment.
Table 18: Body composition in a dry base weight of Nile tilapia fingerlings (10g) fed diets in experiment II. Values in the same column with different letters are significantly different (P< 0.05)
Table 19: Composition of date pits carbohydrates (excl. sugars) (% of dry weight) (FAO, 1999)
List of Figures:

Figure 1 and 2: An overview of the fish lab in the college of Food System and Arid Land agriculture in UAE University, Al Ain. 48

Figure 3: Culture system used in the present study 49

Figure 4: Picture of Nile tilapia 49

Figure 5: Changes in the weights of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I. 62

Figure 6: The ADG of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I. 62

Figure 7: The % weight gain of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I. 63

Figure 8: The %SGR of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I. 63

Figure 9: Feed conversion ratio (FCR) of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I. 64

Figure 10: The PER of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I. 64

Figure 11: Changes in the weight of Nile tilapia adults (50g) fed varying levels of date pits in experiment I. 69

Figure 12: Effect of date pits levels on ADG of Nile tilapia adults (50g) fed diets in experiment I. 69

Figure 13: Effect of date pits levels on % weight gain of Nile tilapia adults (50g) fed diets in experiment I. 70
Figure 14: Effect of date pits levels on %SGR of Nile tilapia adult (50g) fed diets in experiment I.

Figure 15: Effect of date pits levels on FCR of Nile tilapia adults (50g) fed diets in experiment I

Figure 16: Effect of date pits levels on PER of Nile tilapia adults (50g) fed diets in experiment I

Figure 17: Effect of date pits levels on NER of Nile tilapia adults (50g) fed diets in experiment I

Figure 18: Change in the weight of Nile tilapia fingerlings (10g) fed diets in experiments II.

Figure 19: Effect of date pits levels and treatment on ADG of Nile tilapia fingerlings (10g) fed diets in experiment II.

Figure 20: Effect of date pits levels and treatment on %weight gain of Nile tilapia fingerlings (10g) fed diets in experiment II.

Figure 21: Effect of date pits and treatment levels on %SGR of Nile tilapia fingerlings (10g) fed diets in experiment II.

Figure 22: Effect of date pits levels and treatment on FCR of Nile tilapia fingerlings (10g) fed diets in experiment II.

Figure 23: Effect of date pits levels and treatments on crude fat of Nile tilapia fingerlings (10g) fed diets in experiment II.
Introduction
Introduction

The United Arab Emirates is one of the major date palm farming and date producing countries in the world. This is due to the encouragement, support and awareness of H.H Sheikh Zayed bin Sultan Al Nhiyan, president of the United Arab Emirates, to the importance of that cherished tree to our lives. A great attention has been given to date palm agriculture in recent years. As a result, the number of date palm trees has reached 40,700,000 trees, distributed all over the county. Abu Dhabi alone has about 33,476,000 palm trees. Date production from date palm trees was about 757,601 tons in the beginning of the year 2002 (Ministry of Agriculture and Fisheries, MAF, 2002). It is known that about 10-15 % of date is in the form of date pits, from this estimation one can realize the amount of date by-products produced form this industry, would reach 75,000-100,000 ton in 2002.

In addition to the importance of date palm as a producer of date fruit, date palm by-products are used for other purposes such as animal feed. This is indicated in a number of studies using sheep (Tag El- Din and Nour, 1996; El Hag et al., 1996; Hmeidan et al., 1996), poultry (Hmeidan et al., 1996; Najib et al., 1996; Hussein et al., 1998), Calves (El Hag and El Khanjari, 2000) as experimental animals.

However the use of date byproducts as a feed ingredient for fish was not well investigated. Few studies were conducted on the use of date by-products for common carp (Al Asgah, 1987) Nile tilapia (Omar and Nour, 1996; Belal and Al Jasser, 1997) and blue tilapia, Oreochromis aureus (Yousif et al. 1996). These studies found that date by-products could be used as a nutritional source for these fishes.
Tilapia is the second most important cultured fresh water fish species in the world, after carps. Therefore the production of farmed tilapia has jumped from 706,238 ton in 1995 to 1,265,780 ton in 2000 with a value of 56,466,981 9 $ US (FAO, 2002). World cultured tilapia productions from 1995 to 2000 are given in table (1). Tilapia is an excellent candidate for aquaculture, because (1) it can reproduce easily in captivity and has short generation time (Pullin and Lowe-McConnell, 1982), (2) it has the ability to utilize a wide range of natural food and artificial feed, (3) it can tolerate a wide range of environmental conditions, (4) it has rapid growth rates (El-Sayed and Teshima, 1991), (5) it can resist stress and disease (Lovell, 1980; Jauncey and Ross, 1982), (6) it can feed on low trophic levels and accept artificial feeds immediately after yolk-sac absorption (El-Sayed and Teshima, 1992).

Several alternative nutrient sources have been tested for Tilapia culture, for many years. However, little attention has been paid to the use of dates and date by-products as fish feed ingredients.

The present study was conducted to investigate the use date pits as an energy source for two sizes (10 g and 50 g) of Nile tilapia.
Table 3: World cultured tilapia production from 1995 to 2000 (FAO, 2002):

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>706,238</td>
</tr>
<tr>
<td>1996</td>
<td>812,805</td>
</tr>
<tr>
<td>1997</td>
<td>926,756</td>
</tr>
<tr>
<td>1998</td>
<td>944,377</td>
</tr>
<tr>
<td>1999</td>
<td>1,099,053</td>
</tr>
<tr>
<td>2000</td>
<td>1,265,780</td>
</tr>
</tbody>
</table>
Literature Review
Literature Review

Taxonomy of Tilapia and Most Cultured Species:

Tilapias belong to family Cichildae. They are grouped into the following genera:

1. *Sarotherodon* and *Oreochromis* species, also called mouth-brooders: The female incubates and hatches her eggs in her mouth after they are laid and the male fertilizes them. They are microphagous fishes that exhibit biparental, parental and maternal care of their young. Most cultured species of this genus are *Oreochromis mossambicus*, *O. niloticus*, *O. aureus*, and *O. galilaeus* (Bardach et al., 1972; Stickney and Hesby, 1977; Collins and Smitherman, 1978; Miller, 1979; Santiago et al., 1987).

2. Tilapia species, also called Substrate-spawners: The eggs are laid and hatched on the bottom substrates in a nest dug by the male and female. The parents guard their eggs and fry, but do not protect them in their mouths. They are macrophagous fishes. The most popular cultured species are *Tilapia Zillii* and *T. rendalli* (Kanazawa et al., 1980a, b; El-Sayed, 1987).

The cross-breeding between and among tilapias has resulted in a wide variety of tilapia hybrids. Among these, red tilapia (cross-breeding between *O. mossambicus* and *O. niloticus*) (Kuo, 1988; Chang et al., 1988) and Florida red tilapia (*O. mossambicus* X *O. urolepis hornorum*) (Watanabe et al., 1988a, b) are the most common.

Nutrient Requirements of Tilapia:

The nutrition of tilapia is similar to that of other animal species. That is, tilapia require the same nutrients as other animals, for normal metabolic functions. However, the amounts of a particular nutrient needed by tilapia may differ from that of other animals.
Tilapia nutrition plays an important role especially under conditions of high stocking density, when natural food supply is not sufficient. The formulated feeds should be nutritionally balanced in terms of their protein, carbohydrates, fat, etc., and should also contain vitamins and minerals for optimal growth and reproduction performance. A deficiency in one or more of the essential nutrients would reduce performance and may cause disease or even death. The nutrient requirements of tilapia are summarized in the following review.

1. Protein and Amino Acid Requirements:

The quantitative protein requirements of tilapia have been studied by many authors. For *O. niloticus* fry to 5 g fingerlings, 30 to 47 % proteins were found to produce maximum growth (Appler and Jauncey, 1983; Tacon et al., 1983; Appler, 1985; De Silva and Perera, 1985; Wee and Tung, 1988; De Silva et al., 1989; Teshima et al., 1985a; El Sayed and Teshima, 1992; Jovert et al., 1993). In addition, *O. niloticus* weight (0.56 g) fed on a casein:gelatin (3:1) diet required 35% protein for optimum growth (Teshima et al., 1985 a). Growth, feed efficiency and protein and energy utilization for *O. niloticus* fingerlings increased with increasing protein from 25 to 30 % (Omar, 1994). Siddiqui et al. (1998) found that Nile tilapia receiving 45 % dietary protein spawned more frequently than those receiving 25 % dietary protein. The number of eggs per female was significantly higher for female fed the 45 % dietary protein. Furthermore, El-Sayed et al. (2002) found that the Nile tilapia receiving 40 % dietary protein spawned more frequently in high salinity level.
Studies on *T. zillii* (Teshima et al., 1978; Mazid et al., 1979, El-Sayed, 1987), *O. aureus* (Winfree and Stickney, 1981) and *O. mossambicus* when dietary protein is increased up to a certain level, growth rates were increased, then decreased with further increase in protein levels in the feed.

*Oreochromis mossambicus* weight 0.5-1.0 g (Juancey, 1982), 1-2.5 g (Cruz and Laudencia, 1977), 12-70 g fish (Jackson et al., 1982) requires 40 %, 29-38 % and 30 % protein, respectively. In addition, 36 % protein was required by 0.3-0.5 g *O. aureus* (De Silva and Stickney, 1978) and 34 % for 2.5-7.5 g (Winfree and Stickney, 1981) for optimal growth. In the mean time, optimum weight gain and feed conversion of *T. zillii* fingerlings (1.67 g) fed casein-based semipurified diets were obtained at 30-35 % crude Protein (Teshima et al., 1978; Mazied et al., 1979).

In the mean time, optimal protein requirement of tilapia hybrid (*O. niloticus* X *O. aureus*) (Shiau et al., 1987) and (*O. niloticus* X *O. hornorum*) (Yung et al., 1989), Florida red tilapia (Watanabe et al., 1990; Mansour, 1997) ranged from 28-32 % of the diet.

It is obvious, therefore, that between 25 and 45 % dietary protein were required for optimum growth of tilapia, depending on culture conditions, fish species and size and protein and energy sources (De Silva and Gunasekera, 1989). The protein requirements of farmed tilapia is summarized in table 2.
<table>
<thead>
<tr>
<th>Species</th>
<th>Size (g)</th>
<th>Protein</th>
<th>Requirements</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>O. niloticus X O. aureus</em></td>
<td>145-242</td>
<td>FM+CSM</td>
<td>20</td>
<td>Cisse, 1988</td>
</tr>
<tr>
<td></td>
<td>1.24</td>
<td>FM</td>
<td>32</td>
<td>Shiau et al., 1987</td>
</tr>
<tr>
<td><em>O. niloticus X O. hornorum</em></td>
<td>14.5</td>
<td></td>
<td>30.5</td>
<td>Luquet, 1989</td>
</tr>
<tr>
<td><em>O. mossambicus X O. hornorum</em></td>
<td>8.87</td>
<td></td>
<td>28</td>
<td>Watanabe et al., 1990</td>
</tr>
</tbody>
</table>

FM: Fish Meal  
SBM: Soybean Meal  
BM: Bone Meal  
CSM: Cotton Seed Meal
Table 2: Protein requirements of cultured tilapia:

<table>
<thead>
<tr>
<th>Species</th>
<th>Size (g)</th>
<th>Protein</th>
<th>Requirements</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>O. niloticus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fry</td>
<td>0.002-0.028 FM</td>
<td>45%</td>
<td>28.30</td>
<td>De Silva and Perera, 1985</td>
</tr>
<tr>
<td></td>
<td>0.09</td>
<td>-</td>
<td>45</td>
<td>Jovert et al., 1993</td>
</tr>
<tr>
<td></td>
<td>0.56 Casein/Gelatin</td>
<td></td>
<td>35</td>
<td>Teshima et al., 1985</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
<td>FM</td>
<td>40</td>
<td>Siddiqui et al., 1988</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>Casein</td>
<td>40</td>
<td>Kanazawa et al., 1982</td>
</tr>
<tr>
<td></td>
<td>1.29</td>
<td>Casein</td>
<td>40</td>
<td>Teshima et al., 1982</td>
</tr>
<tr>
<td></td>
<td>1.5-7.5 Casein/Gelatin</td>
<td>40</td>
<td>36</td>
<td>Lim (undated)</td>
</tr>
<tr>
<td></td>
<td>3.50</td>
<td>Casein</td>
<td>30</td>
<td>Wang et al., 1985</td>
</tr>
<tr>
<td></td>
<td>6.1-16.5 FM</td>
<td></td>
<td>30</td>
<td>De Silva and Radampola, 1991</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>FM+SBM+BM</td>
<td>27.5</td>
<td>Wee and Tuan, 1988</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Egg albumen</td>
<td>28-30</td>
<td>Yong et al., 1989</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>FM</td>
<td>30</td>
<td>Siddiqui et al., 1988</td>
</tr>
<tr>
<td>Fry</td>
<td>0.50-1.00 FM</td>
<td>40</td>
<td></td>
<td>Jauncey, 1982</td>
</tr>
<tr>
<td></td>
<td>1.00-2.50 FM+SBM+CM</td>
<td></td>
<td>29-38</td>
<td>Cruz and Laudenica, 1977</td>
</tr>
<tr>
<td></td>
<td>6-30</td>
<td>FM</td>
<td>30-35</td>
<td>Jauncey and Ross, 1982</td>
</tr>
<tr>
<td><em>O. mossambicus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fry</td>
<td>0.30-0.50 SBM or FM</td>
<td></td>
<td>36</td>
<td>Davies and Stickney, 1978</td>
</tr>
<tr>
<td></td>
<td>2.50</td>
<td>Casein/albumen</td>
<td>56</td>
<td>Winfree and Stickney, 1981</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>Casein/albumen</td>
<td>34</td>
<td>Winfree and Stickney, 1981</td>
</tr>
<tr>
<td><em>T. zillii</em></td>
<td>1.35-1.80 Casein/Gelatin</td>
<td>35</td>
<td></td>
<td>Mazid et al., 1979</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>Casein/Gelatin</td>
<td>35</td>
<td>El-Sayed, 1987</td>
</tr>
</tbody>
</table>
1.1. Essential Amino Acid Requirements:

There are approximately twenty-five different amino acids present in feed protein, of which about 20 or more enter into the make-up of fish tissue (NRC, 1981). Some of these amino acids are not essential dietary components, because fish can synthesize them from other amino acids or nutrients. However, ten of these amino acids cannot be synthesized either in sufficient quantities or at all in fish body and must be provided with the diet. They are known as the essential amino acids (EAAs). The EAAs required by fish are given in table 3 (NRC, 1981).

Protein quality is influenced primarily by amino acid profile. If one or more of the EAAs is not available, or limited from the food source, deficiency signs including retardation in growth rates, well appear. It is, therefore, necessary to obtain sufficient knowledge of the specific amino acid requirements of cultured fish species, and prepare mixtures of proteins supplemented with the deficient amino acids to achieve maximum growth and protein efficiency.

Few studies have investigated the essential amino acid requirements of some tilapia. Jackson and Capper (1982) estimated the lysine (1.62 % diet), methionine (0.53 %), and arginine (1.52 %) requirements of *O. mossambicus*, by using practical diet containing 40 % crude protein. Santiago and Lovell (1988) determined the 10 essential amino acid requirements for *O. niloticus* fry using casein/gelatin diets, with profile similar to 28 % whole egg protein except for the test amino acid. That work represented the most extensive and complete study on the EAA requirements of tilapia. However, the values reported by Santiago and Lovell (1988) were significantly higher than those reported by Jauncey et al. (1983) on *O. mossambicus*. Jackson and Capper (1982)
a 40% protein diet fed to *O. mossambicus* resulted in a decrease in fish growth. Similar patterns were reported on *O. niloticus* (Teshima et al., 1986) and *T. zillii* (El Sayed, 1989). When those species were fed casein/amino acid diets, they grew at a slower rate than fish fed casein/gelatin diets, (table 4).

Table 3: List of essential amino acids in fish diets (NRC, 1981):

<table>
<thead>
<tr>
<th>Essential amino acids</th>
<th>Appriviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>Arg</td>
</tr>
<tr>
<td>Histidine</td>
<td>His</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>Iso</td>
</tr>
<tr>
<td>Leucine</td>
<td>Leu</td>
</tr>
<tr>
<td>Lysine</td>
<td>Lys</td>
</tr>
<tr>
<td>Methionine</td>
<td>Met</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>Phe</td>
</tr>
<tr>
<td>Threonine</td>
<td>Thr</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>Try</td>
</tr>
<tr>
<td>Valine</td>
<td>Val</td>
</tr>
</tbody>
</table>
Table 4: Essential amino acids requirements of *O. mossambicus* and *O. niloticus* as a percent of dietary protein and diet (in parentheses):

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Lys</td>
<td>4.05 (1.62)</td>
<td>3.78 (1.51)</td>
<td>5.12 (1.43)</td>
</tr>
<tr>
<td>Arg</td>
<td>3.80 (1.52)</td>
<td>2.82 (1.13)</td>
<td>4.20 (1.18)</td>
</tr>
<tr>
<td>His</td>
<td></td>
<td>1.05 (0.42)</td>
<td>1.72 (0.48)</td>
</tr>
<tr>
<td>Thr</td>
<td></td>
<td>2.93 (1.17)</td>
<td>3.75 (1.05)</td>
</tr>
<tr>
<td>Val</td>
<td></td>
<td>2.20 (0.88)</td>
<td>2.80 (0.78)</td>
</tr>
<tr>
<td>Leu</td>
<td></td>
<td>3.40 (1.35)</td>
<td>3.39 (0.95)</td>
</tr>
<tr>
<td>Iso</td>
<td></td>
<td>2.01 (0.80)</td>
<td>3.11 (0.87)</td>
</tr>
<tr>
<td>Met</td>
<td>1.33 (0.53)</td>
<td>0.99 (0.40)</td>
<td>2.68 (0.75)</td>
</tr>
<tr>
<td>Phe</td>
<td></td>
<td>2.50 (1.00)</td>
<td>3.75 (1.05)</td>
</tr>
<tr>
<td>Try</td>
<td></td>
<td>0.43 (0.17)</td>
<td>1.00 (0.28)</td>
</tr>
</tbody>
</table>
Teshima and Kanazawa (1988) studied the effect of dietary methionine as crystalline EAAs or as supplemental methionine-enriched soybean plastein (SBP) in a 30% protein diet on the growth and feed utilization of *O. niloticus* fry (0.4 g). The casein/gelatin diet produced the best fish performance, while the SBP/gelatin diet gave the lowest fish growth and feed utilization. Supplementing the diet with crystalline methionine did not enhance fish performance. On the other hand, methionine-enriched SBP protein improved fish and feed utilization efficiency. The authors suggested the possible use of methionine-enriched SBP to improve the nutritive value of methionine-deficient plant protein source.

In order to determine the essential amino acid requirements of fish, the availability of the various essential amino acids in the feed ingredients should be determined (Wilson et al., 1981). However, the availability of EAAs varies within and among the various protein sources (Wilson et al., 1981). A diet containing only soybean meal as the protein source would be deficient in methionine and cystine (Ogino, 1980), leading to reduction in fish growth. Fishmeal, on the other hand, contains nearly all the EAAs in the required quantities. Unfortunately, the high cost of fishmeal precludes its exclusive use in fish feed formulation.

1.2. Dietary Protein Sources:

Most of the studies conducted on the determination of the quantitative protein requirements have used high-quality protein sources, such as fishmeal or casein.
Additional studies have been done in the laboratory to evaluate cheaper feedstuffs as alternative sources of dietary protein for practical diets.

1.2.1. Fish Meal:

Fishmeal (FM) has been traditionally used as the main source of dietary protein for fish in aquaculture. The nutritional characteristics of FM protein are similar to the nutritional requirements of cultured finfish (Tacon, 1993). FM contains an excellent EAA profile. Moreover, apart from being a good source of high quality animal protein, FM is also a good source of EAAs, digestible energy, macro and trace minerals, vitamins, and generally acts as a feeding stimulant for most fish species (El Sayed, 1999). However, there is an urgent need for aquafeed industry to reduce its total dependence upon FM as a protein source because the high global demand for FM has resulted in its inadequate supply and increased prices. Thus, many fish nutritionists are exploring the use of other efficient sources. El-Sayed (1999) classified the alternative dietary protein sources for farmed tilapia, Oreochromis sp. as follows:

1. Animal Protein By-products:
   a. Fishery by-products (fish silage, shrimp meal, krill meal, squid meal) and
   b. Terrestrial animal by-products (poultry by-product meal, bone meal, hydrolyzed feather meal)

2. Plant protein source.
   a. Oil seed plants (soybean meal, cottonseed meal/cake, other oil seed by-products (groundnut, sunflower, and rapeseeds))
   b. Aquatic plants
   c. Grain, legumes and plant protein concentrates
3. Single-cell proteins; group of microorganisms including unicellular algae, fungi, bacteria, cyanobacteria and yeast

1.2.2. Animal By-products:

Although animal by-products contain high crude protein contents, they are deficient in one or more of essential amino acids including lysine, methionine and isoleucine (Tacon, 1993). However, these imbalances can be overcome by mixing complementary protein by-products meals so as to obtain the desired essential amino acid profile (De Silva and Gunasekera, 1989).

Many studies have investigated the use of animal by-products as FM replacers in tilapia feed. Davies et al. (1989) found that meat and bone meal (MBM) can replace fishmeal in the diet of *O. niloticus* up to 75%. Meat and bone meal plus Bone meal (BM) in a ratio of 2:3 can replace FM up to 75% for *O. mossambicus* fry. In fact, diets containing MBM or high MBM/BM ratios (3:1 and 2:3) were found to be superior to FM even at 100% substitution level, while hydrolyzed feather meal (HFM) was not recommended because it is deficient in some of the EAA. Tacon et al. (1983) found that MBM or MBM+BM can replace 50% of FM when they were both supplemented with (Met) in diets containing 45% crude protein fed to *O. niloticus* fry. When *O. niloticus* fingerlings were fed BM at 10-50% levels, the best level recommended was 10% (Otubsin, 1987). Generally, 30-66% HFM could replace FM in tilapia diets based on fish species, size, and culture conditions. Bishop et al. (1995) demonstrated that HFM could replace as much as 66% of FM without significantly affecting the growth rates of *O. niloticus* fry. On the contrary, Tacon et al., (1983) found that only 30% of HFM replace FM with no significant decrease in growth of *O. niloticus* fry, while *O. niloticus*
fingerlings showed no decrease in growth when HFM replaced 50% of FM. Further increase in HFM caused a significant decrease in fish growth (Falaye, 1982).

Dried poultry waste (DPW) could be used as another animal protein source for fish. Yousif and Alhadrami (1993) made up five isonitorgenous diets containing 35% protein and composed of FM, DPW or mixture of the two, and fed them to *O. aureus* fry and young. Maximum growth and feed utilization efficiency were obtained with FM diets, while over 5% DPW markedly decreased growth and feed utilization.

Rodriguez-Serna et al. (1996) used animal by product meals (ABM) as a substitute for fishmeal for Nile tilapia, fry. The best growth performance was obtained with FM-based diet, but the results were not statistically different from those obtained with 75% and 100% ABM with soybean oil. A simple cost analysis suggested better economic efficiency when tilapia were fed with 100% ABM. It was concluded that animal by product meal can be used as a sole protein source in commercial diets for Nile tilapia fry, without affecting growth and food utilization of the fish.

Belal et al. (1995) studied the use of chicken offal silage as a replacement for fishmeal, for *O. niloticus* fingerlings. They found that chicken offal silage could make up as much as 20% of *O. niloticus* commercial feed as a replacement for fishmeal without any effect on growth or proximate body composition under the experimental conditions.

El-Sayed (1998) investigated the effects of total replacement of dietary fishmeal (FM) with animal protein sources on the growth, feed efficiency and profit indices of *O. niloticus*. Shrimp meal (SM), Blood meal (BM), meat and bone meal (MBM), BM + MBM mix and poultry by product meal (PBM) replaced FM at a 100% substitution level. The growth of fish fed SM, PBM and MBM was not significantly different from
those fed the FM based diet, while feed conversion and protein efficiency ratios were significantly retarded. Cost benefit analysis of the test diets indicated that these sources were economically superior to FM. The PBM-based diet produced higher carcass lipid than other diets. Fish fed SM, MBM and PBM diets had significantly higher as content.

Fish silage is another FM replacer which has been successfully used as a protein source for tilapia. Fagbenro (1994) fed *O. niloticus* fingerlings isocaloric, isonitrogenous diets containing fish silage as a supplement providing 50 % protein of the total in dry matter. The results indicated that fish fed fish silage diets showed similar growth as those fed the control FM diet.

1.2.3. Plant Protein Source:

1.2.3.a. Oil Seed Meal:

Soybean Meal:

Soybean meal (SBM) is generally considered as one of the best readily available plant protein sources in terms of its protein quality and essential amino acid profile. However, it contains a wide variety of endogenous anti-nutrients such as trypsin inhibitor, which require removal or inactivation through processing prior to its use in aquafeeds (Tacon, 1995). Many studies have been conducted using processed SBM as a FM replacer within tilapia feeds. These studies indicated that between 67 to 100 % of the dietary protein could be supplied in the form of SBM, depending on fish species and size, SBM source and processing method, and culture system (Pantha, 1982; Tacon et al., 1983; Jackson et al.; 1982; Shiau et al., 1989). For example, solvent extract or full-fat
SBM, with or without Met supplementation successfully replaced up to 75% of FM within diets fed to *O. niloticus* (Pantha, 1982; Tacon et al., 1983), *O. mossambicus* (Jackson et al., 1982), and tilapia hybrids (Shiau et al., 1989). Additionally, Shiau et al. (1990) found that weight gain, feed conversion efficiency, protein efficiency ratio and protein digestibility of the hybrid (*O. niloticus* X *O. aureus*) fingerlings fed diets (24% crude protein) in which 30% of FM was replaced by defatted full-fat SBM were not significantly different from those of fish fed the control FM diet.

**Cottonseed Meal:**

Cottonseed meal (CSM) is a good protein source as it contains 26-54% protein depending on the processing method (FAO, 1983; NRC, 1983). It is a more controversial feedstuff, due to its content of gossypol, which limits its use. Gossypol is a yellow phenolic compound found in the genus of cotton gossypium. It was found to inhibit digestive enzymes and contain anti-oxidant, which diminished appetite in many terrestrial animals (Lovell, 1980; Jauncey and Ross, 1982). CSM contains low levels of Cys, Lys, and Met (Jauncey and Ross, 1982). Dietary inclusion levels of 20-30% cottonseed meal have been found to be both safe and useful (Viola and Zohar, 1984; Ofojekwu and Ejike, 1984; Robenson et al., 1984; Jackson et al., 1982; El-Sayed, 1990). El-Sayed (1987) found that *T. zillii* efficiently utilize CSM as a protein source even at a 100% inclusion level. On the contrary, *O. niloticus* exhibited poor growth when fed on CSM-based diets (Ofojekwu and Ejike, 1984).
Other Oil Seed Meals:

Jackson et al. (1982) conducted a study on the potential use of copra, groundnut, sunflower, and rapeseed meals for *O. mossambicus*. They recommended levels higher than 30% of these oilseed meals to be used in practical diets for tilapia. Fifteen% inclusion level of rapeseed in the diet of *O. mossambicus*, was found not to cause significant different than control diet (Davies et al., 1990). The use of sesame seed was limited due to lack of zinc/Lysin in the diet of *T. zillii*. But, when zinc or lysine or both were added to the diet they met fish requirement (El-Sayed, 1987). Recently Olevera-Novoa et al. (2002) found that sunflower seed meal is a suitable feed ingredient for tilapia (*Tilapia rendalli*). They recommended an inclusion level of up to 20% of the dietary protein for best growth.

Macadamia presscake, the by-product from oil extraction process of low-grade kernels of macadamia nuts, was found to be suitable as a dietary protein supplement for Nile tilapia, when incorporated at up to 50% replacement for soybean protein. The quality of macadamia presscake in fish feeds may be limited due to the less-than-optimal amino acid balance in macadamia presscake protein (Balogun and Fagobenro, 1995).

Palm kernel meal can be used at up to 60% in the diet of Nile tilapia (Omoregi and Ogbemudia, 1993). Feeding Nile tilapia up to 35% of palm kernel for 120 days did not adversely affect fish growth (Deoliveira et al., 1997).

Recently Hossain et al. (2002) found that the inclusion of up to 9.7% of untreated Sesbania seed meal (*Sesbania aculeate*) (10% of the dietary protein) in the diet
of Nile tilapia did not affect the growth performance and nutrient utilization of the fish compared to the control diet.

1.2.3.b. Grain, Legumes and Plant Protein:

Olevera-Novoa et al. (1990) found that alfalfa (*Medicago sativa*) can be used as a protein source for *O. mossambicus*, and it can be included at levels of up to 35% of the dietary protein in feeds of tilapia. On the other hand, Yousif et al. (1994) did not recommend the inclusion of dehydrated alfalfa and saltbush (*Atriplex*) in the diet of *O. aureus*.

Leucaena leaf meal has been evaluated as a protein source for tilapia. Pantastico and Baldia (1979, 1980) reported improved growth of *O. niloticus* and *O. mossambicus* fed diets containing up to 100% leucaena leaf meal. On the contrary, Jackson et al. (1982) and Wee and Wang (1987) found that levels exceeding 25% in 30% crude protein diets resulted in a significant reduction in growth and feed utilization efficiency of *O. mossambicus* and Nile tilapia fingerlings, respectively. Similarly, the growth performance of Nile tilapia broodstock (Santiago et al. 1988) and the production of *O. aureus* fry (Badawy et al., 1995) were retarded by increasing leucaena leaf meal in the diets above 40 and 15%, respectively. Cooked or sun-dried leucaena leaf meal produced better growth of Nile tilapia than did sodium hydroxide treated or rumen liquor-incubated leucaena leaf meal (Osman et al., 1996).

It has been reported that plant sources may contain different antinutritional factors that adversely affect fish performance. For example, SBM is limiting in sulfur containing
AA (Met, Lys, Cys) and contains protease (trypsin) inhibitor, phytohaemagglutinin and anti-vitamins. Additionally, CSM contains relatively low levels of Cys, Lys, and Met in addition to its high content of gossypol (a phenolic antinutrient compound) (El-Sayed, 1999). Francis et al. (2001) reviewed all antinutritional factors present in plant derived alternate fish feed ingredients and their effects on the fish.

1.2.3.c Aquatic Plants:

Some aquatic plants contain reasonable protein content, and therefore, could be used as a protein source in aquafeed. Santiago et al. (1987) found that *O. niloticus* fed diet containing up to 42% of *Azolla pinnata* (a fresh water fern) showed good growth. Growth was increased and FCR improved as the level of the dietary *Azolla* meal increased. Survival rates were also not affected by the levels of *Azolla* in the diets. Hassan and Edwards (1992) found that fresh duckweed *lemna perpusilla* was more suitable for Nile tilapia than *spirodela polyrhiz* and the optimal daily feeding rates were 5, 4 and 3% of the total fish body weight on duckweed-dry-basis for fish of 25 to 44 g, 45 to 74 g and 75 to 105 g in weight respectively. In spite of this, Fasakin et al. (1999) found that solar-dried duckweed (*Spireodela polyrhiza* and *L. schelden*) can replace up to 30% of FM in practical diets of Nile tilapia, where they supported fish growth and were cost-effective. On the other hand, Almazan et al. (1986), and El-Sayed (1992) reported extremely poor performance of *O. niloticus* fingerling and adults respectively, when they fed *Azolla pinnata* based diets. Similar results was found for *O. mossambicus* and *T. rendalli* when fed *Azolla microphylla* (Micha et al., 1988).
1.2.4. Single Cell Protein (SCP):

Single cell protein (SCP) has been successfully used as a source of protein in aquafeeds. SCPs are microorganisms including bacteria, yeast and microalgae. Successful incorporation of yeast and bacterial SCP into fish diets at replacement level of 25-50 % of FM has been reported (Andruetto et al., 1973; Beck et al., 1979; Mahnken et al., 1980). Viola and Zohar (1984) found that 50 % of the FM protein in diets for hybrid tilapia (O. niloticus X O. aureus) was successfully replaced by 'pruteen' which is a kind of bacterial SCP. Eurolysine fodder protein (EFP) is a commercial SCP obtained from the bacterium Micrococcus glutaminus, which is used in the industrial manufacture of L-lysine HCl. Davies and Wareham (1988) reported that up to 40 % of the FM in a practical diet for tilapia (O. mossambicus) could be effectively replaced by EFP without a significant reduction in growth performance. Higher substitution levels (67 and 75 %) resulted in substantial reduction in growth rates. Similarly, poor feed conversion and net protein utilization were obtained at 15 and 20 % EFP levels. The authors concluded that these effects might have been due to several factors such as the deficiency of the limiting essential amino acid as has been reported by Atack et al. (1979) and Hilton (1983).

On the other hand, the microalge spirulina spp. successfully replaced 20 % of a commercial eel diet fed to O. mossambicus without adversely affecting fish growth and appetite (Chow and Woo, 1990). Furthermore, El Sayed (1994) founded that up to 50 % FM protein could be successfully replaced by Spirulina meal in sea bream (Rhabdosargus sarba) diets.
2. Dietary Energy Requirements:

Boonyartplin (1978) found that energy, not protein, influence the food consumption by fish. In addition, warm water fishes utilize proteins, carbohydrates (sugar, dextrin and starches) and triglycerides effectively as energy sources. Unlike other warm-blooded animals, fish require less energy to synthesis protein (Lovell, 1979). This is because fish do not have to maintain a constant body temperature (NRC, 1983). They exert less energy to maintain position and movement in water than terrestrial animals (Tucker, 1969) and they excrete most of their nitrogenous wastes as ammonia instead of urea or uric acid, where little energy is needed for ammonia synthesis (Smith et al., 1978a, b).

The energy requirements of tilapia have been extensively studied. These requirements depend on fish species and size, energy source and culture conditions. Teshima et al. (1978) and Mazid et al. (1979) found that *T. zillii* fingerlings required 35-40% dietary protein and 3500 kcal ME/kg for optimum growth. Small *O. aureus* required 56% protein and 4600 kcal DE/kg, while larger fish required only 35% protein and 3200 kcal DE/kg for maximum growth (Winfree and Stickney, 1981). El-Sayed and Teshima (1992) found that a diet containing 45 % protein and 400 kcal/100g was required for best growth and feed utilization efficiency of *O. niloticus* fry.
2.1. Energy Sources:

2.1.1. Lipids and Essential Fatty Acid Requirement:

The lipid requirements of tilapia have been investigated by a number of authors. Teshima et al. (1985a) found that *O. niloticus* fingerlings required 18% dietary lipid for normal growth. However, in young red tilapia, dietary lipid content of 24% had a negative effect on growth, feed conversion, protein efficiency ratio (PER) and net protein utilization (De Silva et al., 1991). El Dahher and Shazly (1993) reported that a diet containing 5% emulsified oil gave the lowest mortality and highest growth, energy and protein retention and PER in Nile tilapia, compared to higher dietary lipid.

Chou and Shain (1996) found that the optimal lipid requirement for hybrid tilapia, juvenile (*O. niloticus* X *O. aureus*) to achieve maximal growth was about 12%.

Palm oil could replace soybean oil in feeds for *O. niloticus* fingerlings without any negative effect on the fish growth body composition (Al-Owafeir and Belal, 1996).

2.1.1.a. Essential Fatty Acid (EFA):

A certain group of unsaturated fatty acids are important in fish nutrition. Therefore known as the essential fatty acids (EFAs). Like the essential amino acids, they cannot be synthesized by fish from other fatty acids, and must be supplied in the diet (NRC, 1981).

Information on lipid and EFA requirements of tilapia is not as complete as for coldwater fishes (Stickney and Hardy, 1989). There is no doubt that essential fatty acids
are required, even though fat-free diets have occasionally given similar growth as complete diets (Stickney and McGeachin, 1983).

**Tilapia** are tropical, herbivorous fish which are able to tolerate full strength seawater. Such unique aspect of tilapia in the ecological and physiological viewpoints assumes that their EFA requirements are probably different from other fishes (Kanazawa et al., 1980 b).

Experiments on EFA requirements of fish have revealed a need for ω-6 or linoleic series instead of the ω-3 fatty acids or the linolenic series, which is required by warm-blooded animals (Castell et al., 1972) and this is true for tilapia. *T. zillii* require either linolenic acid (18:2 ω-6) or (22:4 ω-6) (Kanazawa et al., 1980). Corn oil, soybean oil and safflower oil are also suitable lipid sources for tilapia (Stickney and Hardy, 1989; Takeuchi et al., 1983). A dietary level of 1% linoleic acid (18:2 ω-6) or arachidonic acid (20:4 ω-6) was superior in supporting the growth of *T. zillii* (Kanazawa et al., 1980; El-Sayed, 1987) and *O. niloticus* (Teshima et al., 1982) than dietary ω-3 FA’s. *O. niloticus* was also found to require about (0.5-1.0%) ω-6 FA’s for maximum growth, while ω-3 was not required by the fish (Teshima et al., 1982; Takeuchi et al., 1983).

Studies conducted with blue tilapia *O. aureus* have demonstrated that these fish require relatively high levels of ω-6 FA’s (Stickney et al., 1982; Stickney and McGeachin, 1983). However, such requirements were reduced when low levels of ω-3 FA’s were added to the feed. In addition, diets containing ω-3 FA’s in the absence of ω-6 FA’s resulted in poor growth rates (Stickney and McGeachin, 1983). It is obvious therefore, that ω-3/ω-6 ratio in tilapia feed plays a significant role in fish performance. It was found that the best growth of *O. aureus* was obtained on a diet containing on ω-3: ω-
6 ratio of 1.7.6 (Stickney et al., 1982). Viola and Amidan (1980) found that the FA pattern in fish body reflected that some tilapia species have the ability of elongation and desaturation of FA's. It was also found that *T. zillii* is capable of converting exogenous 18:3 ω-3 to 20:5 ω-3 and 22:6 ω-3 (kanazawa et al., 1980).

### 2.1.2. Carbohydrates Utilization by Tilapia:

The principle function of carbohydrate (CHO) is as an energy source. Although carbohydrates supply less energy per gram than either lipids or protein, they are still the cheapest form of dietary energy supply. They may consist of easily digested sugars to complex cellulose, which is difficult to digest. CHO are not essential for some fishes and their absence does not provoke any ill effects, as the fish are capable of synthesizing carbohydrates from dietary lipid sources, and they can apparently grow on diets devoid of carbohydrates (Cowey and Sargent, 1974).

Although carbohydrates are not essential in some fish feed, they provide several uses. (1) CHO are an immediate source of dietary energy (Buhler and Halver, 1961, Phillips et al., 1966, 1967); as energy reserve stored as glycogen in animal livers and muscles (Wendt, 1964), (2) they form a long-term energy reserve when converted to fat in the body, (3) they can also be used as a precursor for various metabolic intermediates necessary for growth, i.e., dispensable amino acids and nucleic acids (NRC, 1983), and (4) CHO's not only lower the cost of the diets, but they also improve pellet binding of the fish feed. Cereal grain products are also used as 'fillers' to complete feed formula. Dioundick and Stom (1990) found that the best growth rate, survival, FCR and PER of
Tilapia were obtained with 2.5-5% supplemental fiber. They also found that tilapia fed with 10% cellulose-supplemented diets demonstrated depressed growth just as did fish fed the cellulose-free diet.

Tilapia, like other herbivorous species, can efficiently utilize dietary carbohydrate. They can utilize complex carbohydrates such as dextrin or starch more efficiently than simple sugars such as glucose (Shiau and Peng, 1994). In herbivorous fishes, such as tilapia, amylase occurs through the entire digestive tract.

Chromium chloride has been found to improve glucose tolerance, increase the rate of lipogenesis and affects glycogen accumulation in the presence of insulin. Chromium is considered to be a co-factor for insulin activity and part of an organic glucose tolerance factor (Shiau, 1997).

Shiau and Lin (1993) conducted a study to investigate the effect of chromium in tilapia, (O. niloticus × O. aureus). The fish were fed diets containing glucose and starch as the carbohydrate sources. Weight gain, protein and energy deposition was significantly higher in fish fed the starch diet than in those fed the glucose diet. Chromium supplementation significantly increased the weight gain, energy deposition and liver glycogen content in fish fed glucose diet. Delayed plasma glucose plateau and significantly higher body lipid content were observed in fish fed the glucose diet with chromium than in those without chromium supplementation.

Digestibility values as high as 75% to 79% have been reported for wheat flour at a dietary level of 35%, and 50% to 56% for potato starch at a dietary level as high as 85% (Barash, 1983). Dried cassava (or manioc or tapioca); a starch-rich root, is also well utilized at dietary inclusion levels ranging from 30% to 60% (Wee and Ng, 1986; Viola...
Anderson et al. (1984) found that up to 40% glucose, sucrose, dextrin could be efficiently utilized by *O. niloticus*, while fish fed cellulose showed a progressive deterioration in growth as inclusion level was increased. In addition, weight gain of *O. niloticus* was improved with the increase in digestible carbohydrate levels from 20% to 30% (Teshima et al., 1985a). They added that increase in digestible carbohydrate levels from 30% to 40% did not result in a significant increase in weight gain. The authors concluded that the optimum growth was attained on a diet containing 30% digestible carbohydrate when the dietary protein level was fixed at 35%.

*Tilapia zillii* were also found to utilize up to 40% dietary carbohydrate without adverse effect on their performance (El-Sayed, 1987). The performance of tilapia was reported to decrease with increasing dietary cellulose levels, presumably due to their inability to secrete cellulase (cellulose digesting enzyme) (Anderson et al., 1984; Wang et al., 1985; Teshima et al., 1987; El-Sayed, 1991).

The digestibility and utilization of polysaccharides could be improved by cooking. Schmitz et al. (1982) reported a significant increase in cornstarch digestibility by European eels when it was hydrothermally treated and gelatinized. Studies on rainbow trout have also demonstrated that cooked starch was better digested and assimilated than raw starch (Smith, 1976).

Belal (1999) studied the possibility of replacing dietary corn with barley seeds for Nile tilapia feed. He found that barley can replace dietary corn up to 51%, without any reduction in body moisture, crude protein and total ash.

Shiau and Chuang (1995) studied the utilization of disaccharides by tilapia, *O. niloticus* × *O. aureus* and their effect on intestinal disaccharidase activities. Glucose and
starch were also included in the study for comparison. They found that weight gain of fish fed the different carbohydrates were as follows: starch > maltose > sucrose > lactose > glucose. The differences between each group were significant. They found that body lipid content was highest in fish fed the starch diet, followed by those fed the maltose and sucrose diet. Intestinal disaccharidase activities in tilapia was not affected by the carbohydrates ingested. Plasma glucose concentrations were similar in fish fed the disaccharide and starch diets and were lower than those in fish fed the glucose diet. The data suggest that tilapia utilize disaccharide’s better than glucose, but more poorly than starch. Of the disaccharide s, maltose was better utilized, followed by sucrose and lactose.

Shiau and Yu (1999) elucidated the effects of chitin on growth and nutrient digestibility of juvenile hybrid tilapia (O. niloticus x O. aureus). Chitin is a polymer of glucosamine, which is found in shells or walls of invertebrates, fungi and yeast. It is the main component of crustacean, exoskeletons and is made up of calcium oxide and protein units. Chitosan, an amiopolysaccharide, is prepared from shellfish chitin by treatment with alkaline. Both are non-starch polysaccharides and are regarded as components of dietary fiber. Significantly lower body weight gains were observed in fish fed chitin and chitosan containing diets than fish fed the control diet regardless of the supplementation level. The weight gain of fish decreased as dietary chitin and chitosan increased. Higher weight gains were observed in fish fed 5 to 10 % chitin diets than fish fed the chitosan diets. Feed conversion ratio (FCR) followed the same pattern. Lipids and dry matter digestibility were lower in fish fed the 10 % chitin diet than in fish fed the control diet. Lower lipid and dry matter digestibility’s and lower body lipid content were observed in
fish fed chitosan containing diets irrespective of supplementation level. Fish fed 2 to 5% chitin diet had higher lipid digestibility than fish fed chitosan diet. Body lipid content of the fish reflects the general pattern of the lipid digestibility. This suggests that both chitin and chitosan supplementation depress tilapia growth regardless of the supplementation level.

2.2. Protein Sparing Effect By Carbohydrates and Lipids:

Protein Sparing Effect (Action): is the replacement of protein energy by non-protein energy to spare protein for growth. Carbohydrates and lipids should be used to meet the energy requirement, since they are less expensive than protein. Protein sparing effect by dietary carbohydrate is well documented in tilapias.

Tilapia have been reported to utilize dietary lipid more efficiently than carbohydrates, and in turn, dietary lipids may spare more protein than carbohydrates for growth. Studies indicated that increasing dietary oil up to 15% resulted in a significant improvement in protein efficiency ratio and protein productive value for *T. zillii* (Teshima et al., 1978; El-Sayed and Garling, 1988). For *O. niloticus*, up to 12% dietary lipid provided sufficient energy for the fish and produced a protein-sparing effect without negatively affecting digestibility (Lorico-Querijero and Chiu, 1989). The protein-sparing capability increased with increasing dietary lipid content up to 18% for red tilapia fingerlings (De Silva et al., 1991). They added that an increase in dietary lipids to 24% had a negative effect on fish growth, feed conversion, protein efficiency ratio and net protein utilization. Ali and Al Asgah (2001) found that the optimal dietary
carbohydrate/lipid ratio for a maximum growth performance of *O. niloticus* ranges between 2.06 and 4.95.

### 2.3. Protein-to-Energy Ratio (P/E Ratio):

The dietary protein should be utilized for fish growth rather than for energy supply. Knowledge of the optimal levels of lipids and CHO’s and their protein sparing effect can be used effectively in reducing feed costs. However, protein can be used as an energy source if dietary energy intake from carbohydrates or lipid is inadequate (Cowey and Sargent, 1972, 1979; NRC, 1981, 1983). At high dietary protein levels, a proportion of this protein will be delaminated and the carbon-skeleton burned as an energy source. Excessive energy intake at moderate protein levels will lead to fat deposition (Jauncey, 1982; NRC, 1983). Thus the design of practical fish diets is a compromise among protein levels spared for growth with little conversion to energy, and an energy level concomitant with high rates of protein synthesis, without producing excessive deposition of carcass lipid. Therefore, the proper balance between dietary protein and energy (P/E ratio) is essential for the optimum use of fish feed. If the optimum P/E ratio is maintained in the diets, a proportion of dietary protein and energy can be spared as has been demonstrated by Garling and Wilson (1976) on channel catfish.

The P/E reported ratio of tilapia has been extensively studied. It has been found that *T. zillii* fingerlings fed semipurified isocaloric diets with different protein levels, required 35-40 % protein and 100-114 mg crude protein/kcal ME for maximum growth (Teshima et al., 1978; El Sayed 1987). In the meantime, Kubaryk (1980) reported that
small *O. niloticus* grew maximally when the DE/P ratio was 8.3 kcal/g for 36% protein diet. As DE content of the diet increased, food consumption decreased, while the amount of protein in the diet did not affect feed consumption. El Sayed and Teshima (1992) found that the best performance of *O. niloticus* fry fed varying protein and energy levels was achieved at 45% and 400 kcal/100g protein and energy, respectively, with a P/E ratio 110 mg cp/kcal. However, Shiau and Huang (1990) demonstrated that the protein content can be lowered from 24%, which is optimum for tilapia hybrid (*O. niloticus* X *O. aureus*) under sea water conditions, to 21% when the energy level of the feed was maintained at 310 kcal/100g diet with a P/E ratio of 67.7 mg cp/kcal. These studies demonstrated that over an appropriate range of dietary protein and energy, the diet with optimum P/E ratio, produced the best growth and feed utilization. Furthermore, diets containing the same P/E ratio but differing in protein and energy contents produced different growth rates (Winfree and Stickney, 1981).

### 3. Vitamin Requirements:

Vitamins are organic compound that are required in minute amounts for normal growth, reproduction, health and general maintenance of fish metabolism. They are either not synthesized by the organisms or synthesized at rates insufficient to meet organisms' needs. Although, they form only a minute fraction of the diet and they are more catalytic in their fraction, they are critical for the maintenance of normal metabolic and physiological functions (NRC, 1983).
Vitamin requirements of fishes are well documented (NRC, 1983). External vitamin sources must not be included in fish diets, in extensive culture and low-density intensive culture, because natural foods are often abundant enough to provide essential vitamins. Vitamin requirements are affected by the size, age, and growth rate of fishes, nutrient inter-relationships and environmental factors (NRC, 1983).

Vitamin requirements of tilapia have been extensively studied. Stickney et al., (1984) found that *O. aureus* requires 50 mg/kg vitamin C for maximum growth, while lower levels (25 mg/kg) produced pathologic changes including mild scoliosis and hemorrhage of fins, mouth and swim bladder. On the other hand, *O. niloticus* fry, juvenile and fingerlings required 125 mg/100 g dietary vitamin C for optimum growth (Soliman et al., 1986, Abdel Ghany, 1996). Ascorbic acid deficient diets caused a reduction in weight gain, development of skeletal deformities, morbidity, hemorrhages and anorexia (Soliman et al., 1994; Abdel Ghany, 1996). In the case of *O. mossambicus*, the absence of any detectable activity of the enzyme L-gulonolactonoxidase was suggested to indicate the essentiality of L-ascorbic acid. Supplemental ascorbic acid in broodstock fish (*O. mossambicus*) feed improved hatchability and fry condition (Soliman et al., 1985). Anadu et al. (1990) studied growth responses of *T. Zillii* fed diets containing various levels of ascorbic acid (AA) and cobalt chloride (CC). The best growth, food conversion ratio (FCR), and protein efficiency ratio (PER) were obtained with feed containing AA. The group fed diets containing CC showed higher growth rates and PER than those fed the control diet. *T. Zillii* fingerlings showed better performance in terms of growth rate and food conversion ratio with diets containing vitamin C than those containing cobalt chloride.
It has been demonstrated that no dietary choline requirement could be established (Roem et al., 1991). Furthermore, methionine sparing of choline was sufficient to satisfy the requirement. Similar choline sparing by dietary methionine has been reported in channel catfish (Wilosn and Poe, 1988).

Soliman and Wilson (1992) found that dietary pantothenic acid requirement for *O. aureus* was 10 mg of calcium d-pantothenate/kg for optimum growth. Soliman and Wilson (1992) found also that *O. aureus* require 6 mg riboflavin/kg diet for best growth.

Roem et al. (1990) found that vitamin E requirement of *O. aureus* was estimated at 10 mg/kg diet at 3% dietary lipid, and 25 mg/kg diet at 6% dietary lipid when the diets contained 120 mg/kg BHA (butylhydroxyanisole) as antioxidant. Satoh et al. (1987) found that *O. niloticus* fingerlings fed vitamin E-free diets showed no deficiency signs when dietary lipid was low (5%). When dietary lipid level was increased to 10 and 15%, fish fed vitamin E-free diets showed poor growth and appetite. Such signs were reversed when 50mg/kg of α-tocopherol were added to diet. It is suggested that vitamin E requirement should be expressed as a function of dietary lipid levels.

O‘Connell and Gatlin (1994) found that Vitamin D3 was not required for tilapia to utilize dietary calcium for growth and tissue mineralization for fingerling blue tilapia.

4. Mineral Requirements:

Minerals are required by all animals, either in their elemental form or incorporated into specific compounds, for various biological functions such as the formation of skeletal tissue, respiration, digestion and osmoregulation. Fish require at
least 22 minerals, 7 major minerals (calcium, phosphorus, potassium, sodium, chlorine, magnesium, and sulfur) and 15 trace elements (iron, zinc, copper, manganese, iodine, fluorine, cobalt, molybdenum, selenium, chromium, nickel, tin, silicon, vanadium, and arsenic) (NRC, 1983).

Mineral requirements of fish are difficult to determine because fish have the ability to absorb ions from the external environment (Lall, 1979). It is difficult to formulate diets and maintain a culture environment free of minerals to conduct requirement or deficiency studies. Ion exchange across the gills and skin greatly complicates the quantitative determination of mineral requirements (Lall, 1979). In addition, supplementation of dietary minerals may not be necessary, except in the case of those that are required in relatively high concentrations, especially in fresh-water fish.

A number of studies have been conducted on the requirements of tilapia for certain minerals. Dietary calcium has effects on growth and mineral composition of blue tilapia (O’Connell and Gatlin, 1994). Calcium deficiency leads to a reduction of growth, feed efficiency, and bone mineralization (calcium, phosphorus, and total ash) in *O. aureus*. The availability of dietary phosphorus (P) and calcium (Ca) to tilapia depends on dietary P and Ca source and fish size. Robinson et al. (1987) found that the best growth of *O. aureus* fed casein diets supplemented with graded levels of Ca and P was obtained at 0.7 % (7 g/kg) dietary Ca, while bone mineralization was not significantly affected by dietary Ca. On the other hand, about 0.3 % (3 g/kg) P supplementation was adequate for good growth, while 0.5 % (5 g/kg) was required for normal bone mineralization. The requirement for available phosphorus is about the same as those reported for other fish species.
Ishak and Dollar (1968) found that when *O. mossambicus* reared in water containing 25 ppm manganese (Mn) were fed diets containing 2.8 mg/kg manganese, they suffered from poor growth, anorexia, loss of equilibrium and high mortality. Supplementing the diets with up to 35 mg/kg manganese did not result in any improvement; while adding Mn to the water helped the fish overcome some of the deficiency signs. Adding Mn to both the water and the diet gave the best results.

Eid and Ghonim, (1994) found that dietary zinc requirement of *O. niloticus* fingerlings fed purified diets was 30 mg/kg dry diet. Common zinc deficiency signs such as reduced growth rate and high mortality have been observed in rainbow trout, common carp and channel catfish, whereas a high incidence of cataracts has been associated with zinc deficiency in rainbow trout and carp (Ogino and Young, 1978 and 1979).

5. Feeding Regimes:

Lovell (1995) reported that tilapia are frequent feeders because they have small, rudimentary stomach, which make them benefit from several feeding per day. Feeding regimes for tilapia in aquaculture can be classified into three main strategies for best growth and feed utilization, and they are as follows:

1. Restricted feeding levels: in this strategy some percentage of fish body weight is given daily for fish (Kubryk, 1980; De Silva et al., 1986; Siraj et al., 1988).
2. *ad libitum*: in this strategy feed is available for fish all the time (Hargreaves et al., 1986). The disadvantage of this strategy is that some of the feed are wasted.
3. Satiation feeding: in this strategy fish is fed with excess feed until satiated at frequent intervals (Balarin and Hatton, 1979)

The optimum growth of *O. niloticus* was achieved at a frequency of four times per day (satiation), but when the fish were fed a restricted diet (3 % bw/day), the best performance was achieved at one or two daily feedings (De Silva et al., 1986). On the contrary, Kubaryk (1980) showed that food consumption and weight gain were maximal when Nile tilapia were fed to satiation four times daily, while fish fed two times daily gained less weight and fish fed eight times daily gained no more than those fed four times. On the other hand, Teshima et al., (1987) found that weight gain of young *O. niloticus* (0.36 g) increased with the increase of feeding levels. They added that weight gain of the large fish was not significantly affected by feeding rate. Viola and Arieli (1983) examined the effects of feeding rate (1.5 %, 2.25 % and 3 % day) and protein level (25 % and 30 %) on the performance of adult *O. niloticus* (120 g). They concluded that optimum performance was obtained at 2.25 % level. On the other hand, feeding rates of 30 % to 45 % BW/day were adequate for rearing *O. niloticus* fry using exclusively a formulated dry diet containing 35 % cp (Santiago et al., 1987; El-Sayed, 2002 a). This is near the estimated daily rate of 20 % to 30 % reported by Mélard and Philippart (1980) for *O. niloticus* (0.5 g).

Survival rate and growth of *O. mossambicus* fry and (*O. niloticus* X *O. aureus*) hybrids was improved as feeding rate increased, irrespective of the stocking density (Macintosh and De Silva, 1984).
6. Exogenous Enzymes:

Exogenous Enzymes have been developed to target anti-nutritive factors as non-digestible fiber that impeded the digestion and adsorption of nutrients from the animal's diet by reducing the gut viscosity or by releasing nutrients. They have the ability to increase digestibility of nutrients, leading to greater efficiency in production and reproduction (Chesson, 1993).

Exogenous enzymes added in animal feed include the following enzymes (www.biocon.com):

1. **Amylase**: It is widely used as a fungal α-amylase which helps in the digestion of starch and can readily hydrolyze starch molecules into smaller oligosaccharides and eventually into glucose and maltose. It functions in upper digestive tract to correct incomplete starch digestion. Alpha-amylase breaks down α-glycosidic bonds inside the starch molecules.

2. **Protease**: It helps in the availability of low grade proteins releasing readily digestible peptides and easily absorbed amino acids. Protease increases digestive capacity of animals and birds and also ensures availability of adequate nutrient supply for better growth and performance.

3. **β-Glucanase**: It digests high molecular weight β-glucanase in grain and cereal based feeds and can be used in the treatment of endosperm cell walls which contains about 70% β-glucanase. Addition of β-glucanase to grain based feed offers solution to many problems associated with β-glucanase.

4. **Cellulase**: The use of cellulase enzyme in animal feed industry is to degrade cellulose. Cellulose is a major component of cereal cell walls. Cellulase enzyme
catalyses the hydrolytic break down of cellulose. It degrades mainly fiber components in the intestinal tract.

5. **Hemicellulase**: It has the ability to degrade various plant fibrous materials, to facilitate extractions, improve separations, reduce viscosity and modify or completely hydrolyse cellulose. It degrades fiber components in intestinal tract.

6. **Lipases**: They are useful in feed for the improvement of fat digestion.

7. **Xylanase**: It digests high molecular weight arabinoxylans in animal feeds and can be used in the treatment of endosperm cell walls of feed grains and vegetable proteins. Addition of xylanase to feed offers solution to many problems associated with arabinoxylans. It functions through the gastro-intestinal tract to reduce intestinal viscosity and degrades cereal cell walls. Xylanase- endo-enzyme which specifically catalyses the hydrolytic break down of xylan (split β-1,4-bonds between xylose molecule).

Exogenous enzymes have been widely used in animal feeds, with varying results. Medel et al. (2002) found that heat processing of barley improved piglet growth during the first 14 days of weaning and increased apparent digestibility of starch. However, enzyme supplementation had no effect on the performance of piglets, but improved the overall digestibility of barley diets of growing pigs (Yin et al., 2000). It has also been found that supplementing piglets feed with NSP (Non-starch polysaccharides) degrading enzymes enhanced the feed conversion efficiency (Gill et al., 2000).

On the other hand, Viverso et al. (1994) found that the addition of enzyme to heated or non-heated barley diet of broilers, had a positive effect on performance and digestibility of nutrients. Similarly, inclusion of enzymes with cereals diets improved
feed efficiency and weight gain of broilers (Flores et al., 1994). Although enzyme has no effect on piglets growth (Valaja et al., 1998), supplementation of microbial phytase improved digestibility of nitrogen, amino acid, starch and lipids, with these improvements being eventually reflected in enhancements in digestible energy and apparent metabolizable energy (Camden et al., 2001). Dietary supplementation of β-glucanase up to 250 g/kg of barley not only enhanced body weight gains of growing broiler, but also improved the live weight of six-week old broilers (Yu et al., 1998; Steenfeldt et al., 1998). Xylanase supplementation was also studied for chicken (Hew et al., 1998). When the enzymes are properly used, they can produce significant improvements in chick performance and can reduce the excretion of undigested nutrients (Marguardt et al., 1996).

The use of Exogenous enzymes in aquafeed is a new trend in aquaculture nutrition. Very few studies have been conducted in this regard. Divakaran and Velasco (1999) studied the effect of proteolytic enzyme addition to a practical feed on growth of the pacific white shrimp, *Litopenaeus vannamei*. Although *in vitro* digestibility indicted the presence of active enzymes in feed, the feeding trial revealed that shrimp growth was not enhanced by the inclusion of proteases in the feed. El Dahher (1999) studied the effect of heat-treated feed and exogenous zymogen on survival and growth of grey mullet, *Liza ramada*, larvae. He found that growth rate was increased with the increase in the inclusion of exogenous zymogen, suggesting that it could be used as a source of digestive enzymes by the larvae.
7. Date By-products as Feed Ingredients:

Date palm tree is one of the most wide spread cultivated trees in the world. It has been cultivated as early as 4000 B.C. (FAO, 1999). Phoenix dactylifera L. is the date palm tree of arid and semi-arid region in North Africa and Arabian countries. It always influences human life in these areas. Date palm also has an environmental impact in desert climate (Ahmed et al., 1995). Table 5 contains major countries in date production.

Although date fruit provides a concentrated energy food, several elements are missing for complete nutrition. When these elements are supplied by other available foods the resulting uniquely simple diet becomes sustaining (Lambiotte, 1982). Average chemical composition of ripe date is given in table 6. Sawaya et al (1983) studied the physical measurement, proximate analysis and chemical composition of 25 date cultivars grown in Saudi Arabia at the Khalal (mature color) and tamer stages. They found that there is low percentage of fat and nitrogen in both stages of development, a high fiber content and proper amount of ash. Levels of fat, nitrogen and fiber are reduced from the stage of khalal to the stage of tamer, while ash stayed constant in both stages. Proximate analysis of minerals showed high concentration of potassium, low concentration of sodium and fair amounts of calcium, phosphorus and magnesium. The micro-nutrient content revealed fair levels of ferrous, cupper, zinc, and traces of Manganese. Changes from khalal to tamer stage coop the reduction in all minerals of all kinds of cultivars.
Table 5: Major date palm producers in 2001 (FAO, 2002):

<table>
<thead>
<tr>
<th>Countries</th>
<th>Production (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egypt</td>
<td>1,102,350</td>
</tr>
<tr>
<td>Iran Islamic Republic</td>
<td>900,000</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>712,000</td>
</tr>
<tr>
<td>Pakistan</td>
<td>550,000</td>
</tr>
<tr>
<td>Iraq</td>
<td>400,000</td>
</tr>
<tr>
<td>Algeria</td>
<td>370,000</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>318,000</td>
</tr>
</tbody>
</table>

Table 6: Average composition of ripe date (Lambiote, 1983):

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>10</td>
</tr>
<tr>
<td>Protein</td>
<td>1.9</td>
</tr>
<tr>
<td>Water</td>
<td>13.8</td>
</tr>
<tr>
<td>Lipid</td>
<td>25</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>70.6</td>
</tr>
<tr>
<td>Ash</td>
<td>1.2</td>
</tr>
<tr>
<td>Vitamins and minerals</td>
<td>Variable</td>
</tr>
</tbody>
</table>
7.1. Date pits (pips, stones, kernels, or seeds):

As mentioned earlier, UAE is considered one of the leading countries in date production. Date production was doubled since the year 2001, and was increased from about 300,000 tons year 2001 to about 700,000 tones in the year 2002 (MAF, 2002). Date pits is the major by-product of date fruit. The average weight of date pits ranges between 13-15% of the date’s weight (Hussein et al., 1998). This makes date pits production around 100,000 tons in the year 2002 (% date pit weight x date production / 100).

Chemical composition of date pits is given in table 7.

Because of the high amount of nitrogen free extract (NFE) in date pits, many researchers have focused on using date pits in animal feed. About 55-73% of NFE in the date pits is mainly starch (Al-Azzawi, 1960; Rashid and Alwash, 1976; Al Asgah, 1987; Yousif et al., 1996; Hussein et al., 1998; and Ali et al., 1999). Several studies have investigated the use of date pits in animal nutrition (Jumah et al., 1973; Kamel et al., 1981; Al-Asgah, 1987; Vandepopuliere et al., 1995; and Yousif et al., 1996).

Rashid and Alwash (1976) found that the inclusion of date pits in the diet of sheep may increase body weight gain, improve feed efficiency and enhance meat palatability. Similarly, Elgasim et al. (1995) reported that date flesh and date pits were effective in increasing body weight gain and deposition of back fat of sheep. Al-Kinani and Alwash (1975) fed date pits to Awassi sheep. They found that the gain in weight was higher for sheep groups fed large proportions of date pits. Shakir et al. (1969 a) used concentrated mixtures based on date pits but supplemented with high protein meal for feeding Awassi lamb. The concentrate mixtures containing 0%, 40% and 80% date pits were given with green alfalfa as forage. The result of that study showed that the growth of Awassi lamb
increased with the increase of date pits level in the diet. The addition of 14% powdered date pits also significantly increased the body weight of rats (Ali et al., 1999).

Table 7: Average chemical composition of date pits (FAO, 1999):

<table>
<thead>
<tr>
<th>Compound</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>10-20</td>
</tr>
<tr>
<td>Protein</td>
<td>5-7</td>
</tr>
<tr>
<td>Water</td>
<td>5-10</td>
</tr>
<tr>
<td>Lipid</td>
<td>7-10</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>55-65</td>
</tr>
<tr>
<td>Ash</td>
<td>1-2</td>
</tr>
<tr>
<td>Vitamins and minerals</td>
<td>Variable</td>
</tr>
</tbody>
</table>

Hussein et al. (1998) reported that the use of date pits in broiler starter and finisher diets improved body weight of chicks, total body weight gain and the efficiency of feed utilization. Similarly, Al-Azzawi (1960) reported significant improvement in the nutritional quality of barley based diet substituted by 15% date pits, and fed to poultry. In contrast, Jumah et al. (1973), reported that broiler diet supplemented with ground date pits at level of 15% resulted in a significant depression in the final body weight and growth. In addition, Kamel et al. (1981) conducted two experiments to investigate the feeding values of date pits and whole dates for broiler chicks. In the first experiment date pits were included in diets at 5, 10, and 15% replacing wheat-bran and corn with and without zinc (50 ppm) supplementation. In the second experiment whole date were included in four diets at 0, 10, 15 and 47.7% replacing corn as an energy source. Their results indicated that date and date pits supported chick growth as efficiently as the
control diets, except the incorporation of 47.7 % of whole dates resulted in some growth
depression and a slight decrease in feed utilization. Similar results were reported by
Vandepopulieve et al. (1995). Those authors found that 8 to 43 % whole dates, 16 to 43
% date meat and 5 to 27 % date pits supported broiler and quail weights and feed
conversions. The quail breeder diet had ingredient ranges of 10 to 30 % date, 8 to 24 %
date meat and 5 to 15 % date pits. However for the quail breeder, there was a decrease in
feed consumption at 30 % date level, which resulted in decreased weight gain.

El Hag and El Khanjari (2000) evaluated the feeding value of both dates and their
by-products (leaves and pips) and sardines as protein supplements for growing calves and
goats. They found that these locally available and cheap agro-industrial by products could
be used for feeding ruminants in the Sultanate of Oman.

7.2. Pretreatments:

Date palm by-products have been treated to improve their quality. Al-Yousef et
al. (1996), found that the ammonia treated date palm leaves and wheat straw were
palatable enough to be fed on their own to sheep without any supplementation. However,
Ali et al. (1999) removed the fibrous coat of the pits by soaking them in 70 % H₂SO₄ for
30 min. They found that treated pits did not improve body weight of rats.

8. The use of date by products in fish feeds:

Few studies have considered date by-products as fish feed ingredients with
varying results. Al Asgah (1987) studied the possible replacement of date pits for wheat
bran-barley mixture in carp feed. He found that partial replacement of up to 75 %
improved carp growth. On the other hand, Omar and Nour (1993) found that feed and nutrient utilization of tilapia fed on diets containing different varieties of immature date fruit droppings were similar to corn grain diet. Moreover, Yousif et al., (1996) attempted to study the potential of dates and date pits as dietary carbohydrate sources for tilapia (Oreochromis aureus). They reported that dates are not recommended as a carbohydrate source in tilapia diets as they are almost entirely simple sugars. The most important conclusion of their study is that date pits could be incorporated in fish diets as a natural repartitioning agent for obtaining less fatty fish. Similarly, Belal and Al-Jasser (1997) determined the effects of replacing dietary starch with pitted date fruit (15, 30 and 45 %) in Nile tilapia feed. They found that weight gain, feed conversion, specific growth rate and protein efficiency ratio were improved with increasing date fruit up to 45 % of the feed as compared with the starch diet (0 % date diet). The diet containing 30 % date was superior to all other test diets. Body moisture, crude protein and total ash were gradually increased as the level of date in the feeds was increased, while body lipids were reduced.
Materials and Methods
Materials and Methods

The present study was carried out at Arid-land Agriculture Department, College of Food System, UAE University, at Al Ain city (Figure 1 and 2) are in two consecutive experiments as follows:

1) The first experiment was designed to evaluate date by-products (date pits) as an energy source for two different sizes of Nile Tilapia (10 and 50g average weight).
2) The second experiment was conducted to study the effect of acid treatment and supplementation of exogenous enzyme, on the quality of date pits for Nile tilapia.

Culture Facility:

The present study was conducted in a closed, recirculating system (figure 3). The system consisted of 70 L fiberglass tanks. Each tank was connected to a central standpipe surrounded by an external pipe (sleeve), perforated at the bottom to allow self-cleaning of the tank.

Dechlorinated tap water was used throughout the study. Water was supplied by nozzles, which were placed at certain angles to enhance water circulation in the tanks. Continuous water circulation was necessary for tank self-cleaning. Each tank was also provided with an air stone. Drainage water from all tanks was collected into a settling reservoir, where feces and other particulate wastes were removed by siphoning. Water was then passed through a series of tanks containing biological filtration media made up
from many plastic tubes. After filtration, the water was pumped up into a head tank (1000 liter) using 1.5 horse power pump and passed through ultraviolet source (Aquafine, 0.67 Amp., model 1, MP-2-SL) for sterilization and microbial disinfections. Water was then distributed to culture tanks by gravity at a flow rate 4 L/min. Water temperature was maintained at 27°C (± 2°C) through central thermostat.

Fish:

Nile tilapia (*Oreochromis niloticus* Linnaeus, 1757) used in these studies was reproduced. The aquaculture facility, College of Food Systems, UAE University, but the original stock was obtained from Saudi Arabia (figure 4). Fish were collected using hand net. After collection, fish were placed in plastic containers to select the proper size. The fish were counted and weighed collectively to the nearest g and the average initial weight (g/fish) was calculated. Average fish weight was calculated by dividing total fish weight by the number of fish in each aquarium. The fish were placed in rearing tanks having proper water flow (4 L/min) and aeration. Each tank was covered with plastic sheet to prevent fish from jumping.

Two initial fish sizes were used in the experiment number one; fingerlings (10g average initial weight) and adults (50g average initial weight). The fish fingerlings were stocked in the culture tanks (70 L capacity) at 15 fish/tank, while the juveniles were stocked at 10 fish/tank.
Figure 1 and 2: An overview of the fish lab in the college of Food System and Arid Land Agriculture in UAE University, Al Ain.

Figure 1:

Figure 2:
Figure 3: Culture system used in the present study.

Figure 4: Picture of Nile tilapia.
Date Pits:

Date pits were obtained from El Saad Date Factory in Al Ain. Two types of date pits were brought from the factory, full date stones and medium crushed stones. Full stone were soaked in 70% H₂SO₄ for 30 min, followed by washing with a continuous jet of tap water for about 10 min, during which the date pits were hand rubbed against each other to remove the softened coats. Finally the resulting endosperms were finely ground and used in the second experiment. Date stones were finely crushed using feed grinder in the experimental farm College of Food Systems, UAE University at Al Oha. After grinding, date stones were sieved (in 0.85 μm) and stored in labeled containers until used. The chemical composition of untreated date pits are given in table 8.

Table 8: Chemical composition of Date pits used in the experiments.

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter</td>
<td>94.6</td>
</tr>
<tr>
<td>Protein</td>
<td>6.7</td>
</tr>
<tr>
<td>Lipids</td>
<td>12.1</td>
</tr>
<tr>
<td>Fiber</td>
<td>10.42</td>
</tr>
<tr>
<td>Ash</td>
<td>1.0</td>
</tr>
<tr>
<td>NEF</td>
<td>69.8</td>
</tr>
<tr>
<td>GE (kcal/100g)</td>
<td>439</td>
</tr>
</tbody>
</table>
Experimental Diets:

Five isonitrogenous (35 % crude protein), isocaloric (450 kcal GE/100g) practical diets were prepared. Date pits replaced wheat bran in the test diets at 0, 25, 50, 75 and 100 % substitution levels in the first experiment (table 9). In the second experiment, eight isonitrogenous (35 % crude protein), isocaloric (450 kcal GE/100g) practical diets were prepared. Date pits replaced wheat bran at 25 and 50 % levels (D2 and D3), while acid-treated date pits were included in diets D4 and D5. Supplemental exogenous enzyme was added to diets D6 and D7 at 1 g/kg. In D8, acid treated date pits and exogenous enzyme supplementation were adopted (table 10). Exogenous enzyme (Kemzyme HF dry) was obtained from Kemin, Europa N.V., Industry zone, Wolfstee, Toekomstlaan 42, 2200, Herentals, Belgium (www.kemin.com).

Gross energies (GE) of the test diets were calculated based on 5.65, 4.1 and 9.5 kcal/g of protein, carbohydrate and lipid, respectively. Proximate analysis of the test diets was performed as discussed in AOAC (1994) to verify their protein and energy contents.

Diets Preparation:

Test diets used in the present study were prepared as follows:

1. Dry ingredients (FM, Wheat bran, Date pits) were finely ground, sieved and weighed separately.
Table 9: Composition and proximate analysis in a dry base of the test diets fed to Nile tilapia in the first experiment

<table>
<thead>
<tr>
<th>Ingredient (%)</th>
<th>D1 Control</th>
<th>D2 (25%)</th>
<th>D3 (50%)</th>
<th>D4 (75%)</th>
<th>D5 (100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish meal</td>
<td>38.0</td>
<td>40.0</td>
<td>41.0</td>
<td>42.0</td>
<td>43.0</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>52.5</td>
<td>38.5</td>
<td>25.5</td>
<td>12.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Date pits</td>
<td>0.0</td>
<td>13.0</td>
<td>26.0</td>
<td>39.0</td>
<td>50.5</td>
</tr>
<tr>
<td>Soybean oil (Vit. + Min. Mix)</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Binder (CMC)²</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Proximate Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>38.6</td>
<td>39.3</td>
<td>37.8</td>
<td>37.7</td>
<td>36.9</td>
</tr>
<tr>
<td>Lipids</td>
<td>10.4</td>
<td>10.7</td>
<td>10.7</td>
<td>10.5</td>
<td>9.4</td>
</tr>
<tr>
<td>Fiber</td>
<td>4.4</td>
<td>5.7</td>
<td>4.3</td>
<td>5.2</td>
<td>5.4</td>
</tr>
<tr>
<td>Ash</td>
<td>8.9</td>
<td>8.9</td>
<td>8.6</td>
<td>8.2</td>
<td>8.1</td>
</tr>
<tr>
<td>NFE³</td>
<td>37.8</td>
<td>35.4</td>
<td>38.7</td>
<td>38.5</td>
<td>40.3</td>
</tr>
<tr>
<td>GE (kcal/100g)⁴</td>
<td>471.9</td>
<td>469.0</td>
<td>473.9</td>
<td>470.6</td>
<td>463.0</td>
</tr>
</tbody>
</table>

1. Vitamins and Minerals (FARVET, Bladel, Holland). Vitamin mix (per kg of feed): A, 10 000 IU; D, 1500 IU; E, 200 IU; C, 300 mg; K, 6 mg; B2, 20 mg; B12, 0.05 mg; niacin, 200 mg; folic acid, 4 mg; pantothenic acid, 25 mg; biotin, 1 mg; antioxidant, 100 mg. Mineral mix (p.p.m): cobalt, 1; copper, 5; iron, 20; manganese, 75; selenium, 0.1; zinc, 150.
2. Carboxymethylcellulase
3. Nitrogen free extract; determined by difference (100 - (protein + lipid + Ash))
4. Gross Energy: Calculated based on 5.65, 4.1 and 9.5 for protein, carbohydrates and lipids, respectively.
Table 10: Composition and proximate analysis on a dry base of the test diets fed to Nile tilapia in the second experiment

<table>
<thead>
<tr>
<th>Ingredient %</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
<th>D7</th>
<th>D8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>(25%)</td>
<td>(50%)</td>
<td>(25%)</td>
<td>(50%)</td>
<td>(25%)</td>
<td>(50%)</td>
<td>(50%)</td>
</tr>
<tr>
<td>Fish meal</td>
<td>38.5</td>
<td>40.0</td>
<td>41.0</td>
<td>40.0</td>
<td>41.0</td>
<td>40.0</td>
<td>41.0</td>
<td>41.0</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>52.0</td>
<td>38.5</td>
<td>25.5</td>
<td>38.5</td>
<td>25.5</td>
<td>38.5</td>
<td>25.5</td>
<td>25.5</td>
</tr>
<tr>
<td>Date pits</td>
<td>0.0</td>
<td>13.0</td>
<td>26.0</td>
<td>13.0</td>
<td>26.0</td>
<td>13.0</td>
<td>26.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>5.0</td>
<td>4.0</td>
<td>3.0</td>
<td>4.0</td>
<td>3.0</td>
<td>4.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>(Vit + Min Mix)†</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Binder (CMC)²</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Acid treated</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Proximal Analysis

<table>
<thead>
<tr>
<th></th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
<th>D7</th>
<th>D8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>36.85</td>
<td>37.8</td>
<td>37.1</td>
<td>37.4</td>
<td>36.6</td>
<td>37.8</td>
<td>37.0</td>
<td>34.7</td>
</tr>
<tr>
<td>Lipids</td>
<td>10.97</td>
<td>10.4</td>
<td>10.2</td>
<td>10.7</td>
<td>10.3</td>
<td>11.1</td>
<td>10.9</td>
<td>10.6</td>
</tr>
<tr>
<td>Ash</td>
<td>8.21</td>
<td>7.9</td>
<td>7.4</td>
<td>7.8</td>
<td>7.7</td>
<td>7.6</td>
<td>7.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Fiber</td>
<td>5.93</td>
<td>6.2</td>
<td>7.0</td>
<td>5.9</td>
<td>7.0</td>
<td>6.9</td>
<td>7.5</td>
<td>7.8</td>
</tr>
<tr>
<td>NFE³</td>
<td>38.04</td>
<td>37.7</td>
<td>38.3</td>
<td>38.2</td>
<td>38.4</td>
<td>36.6</td>
<td>37.4</td>
<td>39.8</td>
</tr>
<tr>
<td>GE</td>
<td>468.4</td>
<td>467.3</td>
<td>463.5</td>
<td>465.4</td>
<td>462.1</td>
<td>469.5</td>
<td>466.5</td>
<td>456.8</td>
</tr>
</tbody>
</table>

1. Vitamins and Minerals (FARVET, Bladel, Holland). Vitamin mix (per kg of feed): A, 10 000 IU; D, 1500 IU; E, 200 IU; C, 300 mg; K, 6 mg; B2, 20 mg; B12, 0.05mg; niacin, 200 mg; folic acid, 4 mg, pantothenic acid, 25 mg; biotin, 1mg; antioxidant, 100mg. Mineral mix (p.p.m): cobalt, 1; copper, 5; iron, 20; manganese, 75; selenium, 0.1; zinc, 150.

2. Carboxymethylcellulase

3. Nitrogen free extract; determined by difference (100 - (protein + lipid + Ash))

4. Gross Energy: Calculated based on 5.65, 4.1 and 9.5 for protein, carbohydrates and lipids, respectively.
2. Dry, weighed ingredients were mechanically mixed together in a kitchen mixer (to assure the homogeneity of ingredients).

3. Corn oil was added to the mixture few drops at a time with continuous mixing.

4. Warm tap water was added gradually until the diet was molded into small balls.

5. The diet was passed through a commercial meat grinder to form spaghetti like threads.

6. The diet was spread on a metal plate and left to dry using cold air coming from an air condition, for 48 hours.

7. Dried diet was chopped into pellets, which were sieved through standard sieves to separate pellets into the appropriate size required for the fish (smaller pellets (1.7 mm) for smaller fish and larger pellets (3 mm) for larger fish).

8. The diets were stored in labeled plastic bags and stored in the freezer at $-20^\circ$ C until used.

Feeding Regimes:

The fish were fed the test diets for a one-week conditioning period to adapt them to these test diets. After the conditioning period was completed, fish in each tank were reweighed, and their initial weights were recorded.

The diets were fed to the two sized fish, two times a day at 8:00-9:00 am and 15:00-16:00 pm, 6 days a week, at a daily rate of 5% of the body weight, for 70 days, from 25 November, 2000 and to the 3rd of February, 2001 in the first experiment. The
second experiment lasted for 88 days (from 22\textsuperscript{nd} of July and ended on the 11\textsuperscript{th} of October 2001) during which the fish were fed 4\% of their body weight/day, reduced to 3\% beginh of the second month. Fishes were weighed every 10 days, and the amount of feed offered readjusted accordingly.

Data Collection and Sample Analysis:

At the end of each experiment, all fish in each aquarium were netted, counted, weighed and the average final weight (g/fish) was calculated. The fish were stored in labeled plastic bags and frozen for final body composition analysis. Initial body analysis was done on a sample of fish, which was frozen prior to each experiment.

Proximate Analysis:

Proximate composition of dry matter, crude protein, lipid, fat, ash and energy content were determined on the diet and fish (AOAC, 1994).

a. Water Content:

Water determination was accomplished by drying a pre-weighed sample at 60\degree C for 24 hours, and the difference between the final and initial weight represented water content:

\[
\% \text{ Water} = 100 \times \left( \frac{\text{Weight of water}}{\text{weight of wet sample}} \right)
\]
b. **Protein:**

The protein content (on dry weight basis) was determined as total nitrogen content using the micro kjeldahl method. Protein content was calculated by multiplying total nitrogen by 6.25.

\[
\text{% Protein} = \text{% nitrogen} \times 6.25
\]

c. **Lipids:**

Total lipids were determined using the Soxhlet method and diethyl ether was used as an organic solvent.

\[
\text{% Lipid} = 100 \left( \frac{\text{Weight of lipid}}{\text{weight of dry sample}} \right)
\]

d. **Ash:**

Total ash was determined by ashing a pre-weighed dry sample in a porcelain crucible at 500° C in a furnace for about 5 hours. The difference between final and initial weight equaled the ash content.

\[
\text{% Ash} = 100 \left( \frac{\text{Weight of ash}}{\text{weight of dry sample}} \right)
\]

e. **Fiber content:**

Crude fiber was determined by consecutive treatments with sulphuric acid (H2SO4, 12.5 g/l) and potassium hydroxide (KOH, 12 g/l).

\[
\text{% Crude fiber} = \left( \frac{\text{weight of crude fiber}}{\text{weight of sample}} \right) \times 100
\]
Calculation of Fish Performance:

**a. Growth Rate:**

- Average daily gain (ADG) = \((W_2 - W_1)/t\)
- % Weight gain = 100 \((W_2 - W_1)/W_1\)
- Specific Growth Rate (% SGR) = 100 \((\log W_2 - \log W_1)/t\)

Where:

- \(W_1\): initial weight (g)
- \(W_2\): final weight (g)
- \(t\): time (days of experiment)

**b. Feed Utilization Efficiency:**

- Feed conversion ratio (FCR) = dry feed intake (g) / fish live weight gain (g)
- Protein efficiency ratio (PER) = fish weight gain (g) / protein intake (g)
- Protein production value (PPV) = 100 (Protein gain (g)/ protein fed (g))
- Net energy retention (NER) = 100 (Energy gain (kcal)/ energy fed (kcal))

**STATISTICAL ANALYSIS:**

To test the effects of date pits levels and fish size on the performance of fish in the first experiment and to test the effect of date pits levels and treatments on fish
performance in the second experiments, simple linear and non-linear regressions were
performed to correlate the obtained results. One-way and tow-way analysis of variance
(ANOVA) were performed using the method of Tuky (Tuky, 1953), to lest the effect of
date pits inclusion levels and treatments on fish performance.
Results
Results

1. Experiment 1:

This experiment was conducted to determine the effects of date pits inclusion in the diet on the performance of two different sizes of Nile tilapia; fingerlings (10 g) adults and (50 g). The fish were fed practical diets containing varying date pits levels as shown in table 8.

Fingerlings:

The growth rates including average daily gain (ADG), % weight gain and specific growth rate (% SGR), and feed utilization efficiency including feed conversion ratio (FCR), Protein efficiency ratio (PER), protein productive value (PPV) and net energy retention (NER) of the fish fingerlings fed the test diets are summarized in table 11 and graphically represented in figures 5-10.

The results indicated that growth rates were significantly affect by dietary treatments (P<0.05). The ADG, % weight gain and % SGR for the fish fed diet 1 (control diet) were significantly higher than the rest of the groups (P<0.05). However, the difference between growth rates of fish fed date pits were not significant (P>0.05) (figure 6, 7 and 8). The results of the ANOVA of the first experiment are given in table 12.

Feed utilization efficiency, including FCR, PER and NER, was also significantly affected by dietary treatment (P< 0.05), but PPV was not significantly affected (P>0.05). The FC and PER of the fish fed the control diet was significantly better than those fed
date pits-based diets. However, FCR and PER values of fish fed date pits were not significant by different (P > 0.05) (figure 9 and 10).

Table 11: Growth rates, feed conversion efficiency and protein and energy retention of Nile tilapia fingerlings (10 g) fed the test diets in experiment I for 70 days. Values in the same column with different letterers are significantly different (P < 0.05):

<table>
<thead>
<tr>
<th>Test Diet</th>
<th>I.W. g/fish</th>
<th>F.W. g/fish</th>
<th>Feed intake</th>
<th>ADG</th>
<th>%W. gain</th>
<th>% SGR</th>
<th>FCR</th>
<th>PER</th>
<th>PPV</th>
<th>NER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10.2</td>
<td>52.1</td>
<td>71.0</td>
<td>0.60^a</td>
<td>411.3^a</td>
<td>2.3^a</td>
<td>1.7^a</td>
<td>1.5^a</td>
<td>27.0^a</td>
<td>13.9^a</td>
</tr>
<tr>
<td>25%</td>
<td>10.6</td>
<td>37.9</td>
<td>59.8</td>
<td>0.39^b</td>
<td>258.5^b</td>
<td>1.8^b</td>
<td>2.2^b</td>
<td>1.2^b</td>
<td>21.8^a</td>
<td>11.6^a</td>
</tr>
<tr>
<td>50%</td>
<td>9.8</td>
<td>34.1</td>
<td>60.9</td>
<td>0.35^b</td>
<td>252.8^b</td>
<td>1.8^b</td>
<td>2.5^b</td>
<td>1.1^b</td>
<td>18.9^a</td>
<td>9.3^b</td>
</tr>
<tr>
<td>75%</td>
<td>10.2</td>
<td>35.4</td>
<td>58.6</td>
<td>0.37^b</td>
<td>250.5^b</td>
<td>1.8^b</td>
<td>2.3^b</td>
<td>1.1^b</td>
<td>20.5^a</td>
<td>11.1^a</td>
</tr>
<tr>
<td>100%</td>
<td>10.3</td>
<td>30.4</td>
<td>54.1</td>
<td>0.28^b</td>
<td>193.0^b</td>
<td>1.5^b</td>
<td>2.8^b</td>
<td>1.0^b</td>
<td>16.8^a</td>
<td>8.1^b</td>
</tr>
</tbody>
</table>

I.W.: Initial Body Weight g/fish  
F.W.: Final Body Weight g/fish  
ADG: Average Daily Gain  
%W. Gain: Percent Weight Gain  
% SGR: % Specific Growth Rate  
FCR: Feed Conversion Ratio  
PER: Protein Efficiency Ratio  
PPV: Protein Productive Value  
NER: Net Energy Retention
Table 12: Analysis of variance of the results obtained in the first experiment:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Date pits level</th>
<th>Fish size</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADG:</td>
<td>P value</td>
<td>0.036*</td>
<td>0.201 N.S</td>
</tr>
<tr>
<td></td>
<td>F value</td>
<td>3.94</td>
<td>1.87</td>
</tr>
<tr>
<td>% Weight gain:</td>
<td>P value</td>
<td>0.04*</td>
<td>0.21 N.S</td>
</tr>
<tr>
<td></td>
<td>F value</td>
<td>4.05</td>
<td>1.98</td>
</tr>
<tr>
<td>% SGR</td>
<td>P value</td>
<td>0.001 **</td>
<td>0.001 **</td>
</tr>
<tr>
<td></td>
<td>F value</td>
<td>18.15</td>
<td>237.6</td>
</tr>
<tr>
<td>FCR:</td>
<td>P value</td>
<td>0.001 **</td>
<td>0.001 **</td>
</tr>
<tr>
<td></td>
<td>F value</td>
<td>16.03</td>
<td>133.5</td>
</tr>
<tr>
<td>PER:</td>
<td>P value</td>
<td>0.001 **</td>
<td>0.001 **</td>
</tr>
<tr>
<td></td>
<td>F value</td>
<td>14.03</td>
<td>86.75</td>
</tr>
<tr>
<td>PPV:</td>
<td>P value</td>
<td>0.007 **</td>
<td>0.001 **</td>
</tr>
<tr>
<td></td>
<td>F value</td>
<td>6.68</td>
<td>20.23</td>
</tr>
<tr>
<td>NER</td>
<td>P value</td>
<td>0.001 **</td>
<td>0.001 **</td>
</tr>
<tr>
<td></td>
<td>F value</td>
<td>17.05</td>
<td>131.44</td>
</tr>
</tbody>
</table>

* : Significant at 5% level of probability

** : Significant at 1% level of probability

N.S: not significant at 5% level of probability
Figure 5: Changes in the weights of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I.

Figure 6: The ADG of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I.
Figure 7: The % Weight gain of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I.

Figure 8: The %SGR of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I.
Figure 9: The FCR of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I.

Figure 10: The PER of Nile tilapia fingerlings (10g) fed varying levels of date pits in experiment I.
Body composition of fish fingerlings is summarized in table 13. Body moisture, crude protein, and ash were almost similar for all groups, indicating that they were not significantly affected by dietary treatments. On the other hand crude lipid was significantly affected. Increasing date pits level up to 100% caused retardation in body crude lipids.

<table>
<thead>
<tr>
<th>Diets</th>
<th>%Moisture</th>
<th>%Crude Protein</th>
<th>%Crude Lipid</th>
<th>%Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>77.2*</td>
<td>76.7*</td>
<td>5.99*</td>
<td>10.46*</td>
</tr>
<tr>
<td>25 %</td>
<td>76.1*</td>
<td>76.6*</td>
<td>5.34*</td>
<td>10.20*</td>
</tr>
<tr>
<td>50 %</td>
<td>77.1*</td>
<td>77.3*</td>
<td>4.14*</td>
<td>10.81*</td>
</tr>
<tr>
<td>75 %</td>
<td>76.6*</td>
<td>77.9*</td>
<td>5.29*</td>
<td>9.04*</td>
</tr>
<tr>
<td>100 %</td>
<td>78.0*</td>
<td>78.1*</td>
<td>2.67b</td>
<td>11.50*</td>
</tr>
<tr>
<td>Initial</td>
<td>76.3*</td>
<td>80.1*</td>
<td>3.9*</td>
<td>9.70*</td>
</tr>
</tbody>
</table>

Table 13: Body composition in a dry base weight of Nile tilapia fingerlings (10g) fed diets in experiment 1. Values in the same column with different letterers are significantly different (P < 0.05):
**Adult fish:**

For adult fish (50 g), the trends of fish performance were similar to that of fingerlings (table 14). The ADG, % weight gain and % SGR for the control diet were significantly better (P < 0.05) than that of date pits diets (Figure 12, 13 and 14). However, increasing date pits levels from 25 to 100% did not further affect fish growth (P > 0.05).

Feed utilization including FC, PER and NER were significantly different among the test diets (P < 0.05). Fish fed the control diet had significantly better FC, PER, and NER than fish fed date pits (figure 15, 16 and 17). The PPV values for all test diets were not significantly affected (P > 0.05).

Body composition of adult Nile tilapia are shown in table 15. It can be noticed that all parameters, Moisture, crude protein, crude lipid and ash were not significantly affected by the test diets. However, the sum of protein, carbohydrates, lipids and ash in all treatments did not come to a 100%. This may have been due to some errors in flesh sampling and/or chemical analysis.

In terms of the possible effect of size on growth performance and feed utilization of Nile tilapia, two way analysis of variance was calculated. Growth performance for the two sizes of fish including % SGR and % weight gain was found to be significantly affected by date pits levels and fish size (P < 0.05) but there were no interaction between date pits and size (P > 0.05). On the other hand, there was a significant effect of date pits levels, but not fish size on ADG. Furthermore, there was an interaction between size and date pits level on ADG (P < 0.05).
Feed utilization including FCR, PER, PPV, and NER were all significantly affected by date pits levels and by fish size (P < 0.05), but there were no interaction between these factors (P > 0.05).

Comparing fish fingerlings with adults, it appeared that fingerlings performance were better than that of adults. This finding indicates that Nile tilapia fingerlings can utilize date pits more efficiently than adults.

**Table 14: Growth Rates, feed conversion and protein and energy retention of Nile tilapia adult (50g) fed the test diets in experiment I for 70 days. Values in the same column with different letterers are significantly different (P < 0.05):**

<table>
<thead>
<tr>
<th>Test Diet</th>
<th>I.W. g/fish</th>
<th>F.W. g/fish</th>
<th>Feed intake</th>
<th>ADG1</th>
<th>%W. gain2</th>
<th>% SGR3</th>
<th>FCR4</th>
<th>PER5</th>
<th>PPV6</th>
<th>NER7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>50.6</td>
<td>137.3</td>
<td>206.5</td>
<td>1.2a</td>
<td>171.4a</td>
<td>1.42a</td>
<td>2.42a</td>
<td>1.09a</td>
<td>21.3a</td>
<td>9.6a</td>
</tr>
<tr>
<td>25 %</td>
<td>50.7</td>
<td>96.0</td>
<td>179.7</td>
<td>0.7b</td>
<td>89.5b</td>
<td>0.91b</td>
<td>4.00b</td>
<td>0.64b</td>
<td>18.4b</td>
<td>4.3b</td>
</tr>
<tr>
<td>50 %</td>
<td>49.5</td>
<td>89.6</td>
<td>174.4</td>
<td>0.6b</td>
<td>81.0b</td>
<td>0.85b</td>
<td>4.35b</td>
<td>0.61b</td>
<td>11.1b</td>
<td>4.2b</td>
</tr>
<tr>
<td>75 %</td>
<td>50.8</td>
<td>97.6</td>
<td>186.4</td>
<td>0.7b</td>
<td>92.1b</td>
<td>0.93b</td>
<td>3.98b</td>
<td>0.67b</td>
<td>9.0b</td>
<td>3.1b</td>
</tr>
<tr>
<td>100 %</td>
<td>51.0</td>
<td>89.9</td>
<td>170.8</td>
<td>0.6b</td>
<td>75.5b</td>
<td>0.80b</td>
<td>4.42b</td>
<td>0.61b</td>
<td>9.8a</td>
<td>2.6b</td>
</tr>
</tbody>
</table>

I.W.: Initial Body Weight g/fish
F.W.: Final Body Weight g/fish
1ADG: Average Daily Gain
2% W. Gain: Percent Weight Gain
3%SGR: % Specific Growth Rate
4FCR: Feed Conversion Ratio
5PER: Protein Efficiency Ratio
6PPV: Protein Productive Value
7NER: Net Energy Retention
Table 15: Body composition in a dry base weight of Nile tilapia adult (50g) fed diets in experiment I. Values in the same column with different letterers are significantly different (P < 0.05):

<table>
<thead>
<tr>
<th>Diets</th>
<th>%Moisture</th>
<th>%Crude Protein</th>
<th>%Crude Lipid</th>
<th>%Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>76.1(a)</td>
<td>81.6(a)</td>
<td>2.9(a)</td>
<td>9.2(a)</td>
</tr>
<tr>
<td>25 %</td>
<td>76.7(a)</td>
<td>79.7(a)</td>
<td>2.1(a)</td>
<td>10.3(a)</td>
</tr>
<tr>
<td>50 %</td>
<td>76.9(a)</td>
<td>81.4(a)</td>
<td>2.8(a)</td>
<td>13.2(a)</td>
</tr>
<tr>
<td>75 %</td>
<td>77.2(a)</td>
<td>71.3(a)</td>
<td>1.9(a)</td>
<td>13.5(a)</td>
</tr>
<tr>
<td>100 %</td>
<td>76.9(a)</td>
<td>77.4(a)</td>
<td>2.6(a)</td>
<td>11.8(a)</td>
</tr>
<tr>
<td>Initial</td>
<td>76.9(a)</td>
<td>77.3(a)</td>
<td>9.5(b)</td>
<td>8.9(a)</td>
</tr>
</tbody>
</table>
Figure 11: Changes in the weights of Nile tilapia adults (50g) fed varying levels of date pits in experiment 1.

Figure 12: The ADG of Nile tilapia adult (50g) fed varying levels of date pits in experiment 1.
Figure 13: The % weight gain of Nile tilapia adult (50g) fed varying levels of date pits in experiment L.

![Graph showing % weight gain vs. date pits levels](image)

Figure 14: The % SGR of Nile tilapia adults (50g) fed varying levels of date pits in experiment L.

![Graph showing % SGR vs. date pits levels](image)
Figure 15: The FCR of Nile tilapia adults (50g) fed varying levels of date pits in experiment I.

Figure 16: The PER of Nile tilapia adults (50g) fed varying levels of date pits in experiment I.
Figure 17: The NER of Nile tilapia adult (50g) fed varying levels of date pits in experiment L.
2. Experiment II:

This experiment was conducted to evaluate the effectiveness of using exogenous enzymes and acid treatment of date pits for Nile tilapia fingerlings (10g).

The growth rates including average daily gain (ADG), % Weight gain and specific growth rate (% SGR), and feed utilization efficiency including feed Conversion (FCR), protein efficiency ratio (PER), protein productive value (PPV) and net energy retention (NER) of the fish fed the test diets are summarized in table 16 and graphically represented in figures 24-29.

The present results indicated that ADG, % weight gain and % SGR were significantly affected by date pits levels, enzyme addition and acid treatment of (P< 0.05). Furthermore, there were interactions among these factors on ADG and % weight gain. The % SGR was significantly affect by all factors separately (P< 0.05) but there were no interaction among them. It was found that ADG, % weight gain and % SGR values for control diet and the 25 % date pits level were not significantly different. Further, increase in date pits levels significantly reduced growth rates (P < 0.05). The results of the ANOVA of the second experiment are given in table 17.

FCR was significantly affected by date pits levels, enzyme supplementation and acid treatment of date pits (P<0.05), but there were no interaction among these factors. However, FCR values of fish fed the control diets and 25 % date pits were not significantly better than the rest of the diets (P > 0.05). In addition, the PER, PPV and NER were not significant effected by dietary treatments (P> 0.05).

The results indicated also that growth rates and feed utilization efficiency were not significantly affected (P >0.05) by either enzyme supplementation or acid treatment.
or both. Furthermore, these treatments have lead to slight reduction in fish growth ($P > 0.05$).

Table 16: Growth rates, feed conversion and protein and energy retention of Nile tilapia fingerlings (10 g) fed the test diets in experiment II for 88 days. Values in the same column with different letterers are significantly different ($P < 0.05$):

<table>
<thead>
<tr>
<th>Test Diet</th>
<th>I.W. g/fish</th>
<th>F.W. g/fish</th>
<th>Feed intake</th>
<th>ADG</th>
<th>%W. gain</th>
<th>SGR</th>
<th>FCR</th>
<th>PER</th>
<th>PPV</th>
<th>NER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10.3</td>
<td>38.4</td>
<td>104.1</td>
<td>0.32 a</td>
<td>274.6 a</td>
<td>1.5 a</td>
<td>3.54 a</td>
<td>0.8 a</td>
<td>11.9 a</td>
<td>19.6 a</td>
</tr>
<tr>
<td>25 %</td>
<td>9.7</td>
<td>35.5</td>
<td>93.40</td>
<td>0.29 a</td>
<td>266.0 a</td>
<td>1.5 a</td>
<td>3.71 ab</td>
<td>0.6 a</td>
<td>11.3 a</td>
<td>25.2 a</td>
</tr>
<tr>
<td>50 %</td>
<td>10.7</td>
<td>32.7</td>
<td>91.20</td>
<td>0.25 b</td>
<td>206.6 b</td>
<td>1.3 ba</td>
<td>4.15 bc</td>
<td>0.5 a</td>
<td>9.8 a</td>
<td>21.4 a</td>
</tr>
<tr>
<td>25 % + enzyme</td>
<td>10.7</td>
<td>29.2</td>
<td>86.65</td>
<td>0.21 bc</td>
<td>172.9 bc</td>
<td>1.1 ba</td>
<td>4.77 cd</td>
<td>0.4 a</td>
<td>9.8 a</td>
<td>18.9 a</td>
</tr>
<tr>
<td>50 % + enzyme</td>
<td>10.5</td>
<td>28.2</td>
<td>82.55</td>
<td>0.20 bc</td>
<td>168.1 bc</td>
<td>1.1 ba</td>
<td>4.46 cd</td>
<td>0.4 a</td>
<td>9.4 a</td>
<td>16.8 a</td>
</tr>
<tr>
<td>25 % acid treated</td>
<td>10.6</td>
<td>34.7</td>
<td>95.30</td>
<td>0.27 ba</td>
<td>228.4 ba</td>
<td>1.4 a</td>
<td>3.98 ab</td>
<td>0.6 a</td>
<td>11.2 a</td>
<td>24.5 a</td>
</tr>
<tr>
<td>50 % acid treated</td>
<td>10.3</td>
<td>27.1</td>
<td>80.30</td>
<td>0.19 bc</td>
<td>162.6 bc</td>
<td>1.1 ba</td>
<td>4.93 cde</td>
<td>0.4 a</td>
<td>8.8 a</td>
<td>16.6 a</td>
</tr>
<tr>
<td>50 % acid treated + enzyme</td>
<td>10.3</td>
<td>25.4</td>
<td>78.05</td>
<td>0.17 c</td>
<td>146.6 c</td>
<td>1.0 ba</td>
<td>5.32 e</td>
<td>0.3 a</td>
<td>8.6 a</td>
<td>13.7 a</td>
</tr>
</tbody>
</table>

I.W.: Initial Body Weight g/fish
F.W.: Final Body Weight g/fish
ADG: Average Daily Gain
%W. gain: Percent Weight Gain
SGR: Specific Growth Rate
FCR: Feed Conversion Ratio
PER: Protein Efficiency Ratio
PPV: Protein Productive Value
NER: Net Energy Retention
Table 17: Analysis of variance of the results obtained in the second experiment:

<table>
<thead>
<tr>
<th></th>
<th>Date pits level</th>
<th>Treatment</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADG</td>
<td>P value 0.005**</td>
<td>0.006**</td>
<td>0.078*</td>
</tr>
<tr>
<td></td>
<td>F value 18.68</td>
<td>13.17</td>
<td>4.04</td>
</tr>
<tr>
<td>% Weight gain:</td>
<td>P value 0.005**</td>
<td>0.006**</td>
<td>0.08*</td>
</tr>
<tr>
<td></td>
<td>F value 19.01</td>
<td>14.11</td>
<td>4.00</td>
</tr>
<tr>
<td>% SGR:</td>
<td>P value 0.008**</td>
<td>0.008**</td>
<td>0.12 N.S</td>
</tr>
<tr>
<td></td>
<td>F value 15.02</td>
<td>11.93</td>
<td>2.97</td>
</tr>
<tr>
<td>FCR:</td>
<td>P value 0.034*</td>
<td>0.020*</td>
<td>0.179 N.S</td>
</tr>
<tr>
<td></td>
<td>F value 7.49</td>
<td>8.09</td>
<td>2.32</td>
</tr>
<tr>
<td>PER:</td>
<td>P value 0.43 N.S</td>
<td>0.89 N.S</td>
<td>0.54 N.S</td>
</tr>
<tr>
<td></td>
<td>F value 0.72</td>
<td>0.12</td>
<td>0.69</td>
</tr>
<tr>
<td>PPV:</td>
<td>P value 0.429 N.S</td>
<td>0.893 N.S</td>
<td>0.54 N.S</td>
</tr>
<tr>
<td></td>
<td>F value 0.72</td>
<td>0.12</td>
<td>0.69</td>
</tr>
<tr>
<td>NER:</td>
<td>P value 0.795 N.S</td>
<td>0.280 N.S</td>
<td>0.103 N.S</td>
</tr>
<tr>
<td></td>
<td>F value 0.07</td>
<td>1.58</td>
<td>3.40</td>
</tr>
<tr>
<td>Body Moisture:</td>
<td>P value 0.356 N.S</td>
<td>0.422 N.S</td>
<td>0.422 N.S</td>
</tr>
<tr>
<td></td>
<td>F value 1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Body Ash:</td>
<td>P value 0.444 N.S</td>
<td>0.647 N.S</td>
<td>0.187 N.S</td>
</tr>
<tr>
<td></td>
<td>F value 0.67</td>
<td>0.47</td>
<td>2.24</td>
</tr>
<tr>
<td>Body crude protein:</td>
<td>P value 0.354 N.S</td>
<td>0.220 N.S</td>
<td>0.293 N.S</td>
</tr>
<tr>
<td></td>
<td>F value 1.01</td>
<td>1.97</td>
<td>1.52</td>
</tr>
<tr>
<td>Body cure lipids:</td>
<td>P value 0.001**</td>
<td>0.339 N.S</td>
<td>0.016*</td>
</tr>
<tr>
<td></td>
<td>F value 30.43</td>
<td>1.30</td>
<td>8.90</td>
</tr>
</tbody>
</table>

*: Significant at 5% level of probability

**: Significant at 1% level of probability

N.S: not significant at 5% level of probability
Figure 18: Change in the weight of Nile tilapia (10g) fed diets in experiment II.

Figure 19: Effect of date pits levels and treatments on ADG of Nile tilapia fingerlings fed the test diets in experiment II.
Figure 20: Effect of date pits levels and treatments on % weight gain of Nile tilapia fingerlings fed the test diets in experiment II.

Figure 21: Effects of date pits levels and treatments on %SGR of Nile tilapia fed diets in experiment II.
Figure 22: Effect of date pits levels and treatments on FCR of Nile tilapia fed the test diets in experiment II.
Body composition of fish fed the test diets in experiment 2 is given in table 18. It had been found that date pits levels, enzyme and acid treatment of date pits had no significant effect on body composition including moisture, ash and crude protein (P> 0.05). On the other hand crude lipid was significantly affected by date pit level but not by enzyme supplementation or acid treatment (P< 0.05). Body crude lipid in fish was significantly lower in fish fed 50% date pits, either treated or untreated, than in those fed other diets. On the other hand, group 4 (25% date pits + Enzyme) had significantly higher (P> 0.05) crude lipid level than the rest of the groups.

Table 18: Body composition in a dry base weight of Nile tilapia fingerlings (10g) fed diets in experiment II. Values in the same column with different letterers are significantly different (P < 0.05):

<table>
<thead>
<tr>
<th>Diets</th>
<th>%Moisture</th>
<th>%Crude Protein</th>
<th>%Crude lipid</th>
<th>%Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>75.3 a</td>
<td>63.9 a</td>
<td>11.8 a</td>
<td>22.3 a</td>
</tr>
<tr>
<td>25 %</td>
<td>75.8 a</td>
<td>63.8 a</td>
<td>12.0 a</td>
<td>21.6 a</td>
</tr>
<tr>
<td>50 %</td>
<td>76.0 a</td>
<td>62.8 a</td>
<td>11.9 a</td>
<td>21.2 a</td>
</tr>
<tr>
<td>25 % + enzyme</td>
<td>74.6 a</td>
<td>63.7 a</td>
<td>14.2 b</td>
<td>21.0 a</td>
</tr>
<tr>
<td>50 % + enzyme</td>
<td>76.6 a</td>
<td>66.2 a</td>
<td>9.7 ab</td>
<td>22.9 a</td>
</tr>
<tr>
<td>25 % acid treated</td>
<td>75.1 a</td>
<td>64.7 a</td>
<td>12.5 ab</td>
<td>22.1 a</td>
</tr>
<tr>
<td>50 % acid treated</td>
<td>76.7 a</td>
<td>65.4 a</td>
<td>9.9 ab</td>
<td>21.8 a</td>
</tr>
<tr>
<td>50 % acid treated + enzyme</td>
<td>76.9 a</td>
<td>66.1 a</td>
<td>8.0 bc</td>
<td>23.5 a</td>
</tr>
<tr>
<td>initial</td>
<td>76.0 a</td>
<td>61.9 a</td>
<td>15.0 b</td>
<td>20.3 a</td>
</tr>
</tbody>
</table>
Figure 23: Effect of date pits levels and treatments on body crude lipids of Nile tilapia fingerlings fed the test diets in experiment II.
Discussion
Discussion

Since Feed represents more than 50% of aquaculture projects running costs, it is very essential to develop cost-effective feeds to be used as supplementary diets in fish ponds or as complete diets in intensive culture. Such approach is exemplified in fish diets through replacing the expensive ingredients with unconventional, inexpensive materials which mainly depend on by-products from the following sources: a) by-products of plant origin, b) by-products of animal origin and c) agricultural and industrial wastes. Most of these by-products could be used in fish feed formulation.

Date pits is an important agricultural by product in the UAE. It was estimated that the annual date pits production in the UAE is about 100,000 tons. The annual production of date fruit in UAE reaches 757,601 tons (MAF, 2002).

Date by-products have been used as animal feed for a long time. A number of studies have been conducted in this regard. Date by-products have been efficiently utilized by sheep (Tag El-Din and Nour, 1996; El-Hag et al., 1996; Hmeidan et al., 1996), poultry (Hmeidan et al., 1996; Hussein et al., 1998), Calves (El-Hag and El-Khanjari, 2000). However, little information is available on the use of date pits as fish feed ingredient. The present study tended to evaluate date pits as a feed ingredient for Nile tilapia.

From the present results, it was found that using date pits as feed ingredient caused a significant reduction in the growth rates, feed utilization and body lipids of Nile tilapia fingerlings (10g) and adults (50g). This finding is similar to the finding of Yousif et al. (1996), who attempted to study the potential of dates and date pits as dietary
carbohydrate sources for tilapia (*Oreochromis aureus*). They reported that dates are not recommended as a carbohydrate source in tilapia diets as they are almost entirely simple sugars. The most important conclusion of their study is that date pits could be incorporated in fish diets as a natural repartitioning agent for obtaining less fatty fish. The negative effects of date pits on fish performance in the present study may have been due to:

1) Their high fiber contents and/or

2) Their high contents of simple sugars.

Several studies have considered the effects of fiber dietary on different animals. In monogastric animals, the high fiber content of date pits was reported to cause decreased weight gain (Vandepopuliere et al. 1995). Similarly, Shiau et al. (1988) studied the effects on dietary carboxymethylcellelose (CMC) on tilapia hybrids (*Oreochromis niloticus* X *O. aureus*). They found that the increase in CMC in the diets increases stomach emptying time, leading to reducing growth rates and feed utilization efficiency. Similar results were reported by Diondicke and Stom (1990) who found that the best growth rate, survival, FCR and PER of tilapia were obtained with 2.5-5% supplemental fiber. They also found that tilapia fed with 10% cellulose-supplemented diets demonstrated depressed growth compared fish fed the cellulose-free diets. Furthermore, Nile tilapia and *T. zillii* fed increased levels of cellulose had a progressive reduction in growth rates (Anderson et al., 1984; El-Sayed, 1987). The poor performance of tilapia fed high fiber content may have been due to their inability to secrete cellulase (a cellulose digesting enzyme).
Although carbohydrate in date pits represent the largest component (70 to 80%), only a small part of it, consists of simple sugar (glucose and fructose) while the remainder of carbohydrates are complex sugars. With special eye for its use as an animal feed, and together with crude fiber content, this part can be further split up into cellulose, hemicelluloses, lignin and ash (FAO, 1999) (table 19).

Table 19: Composition of date pits carbohydrates (excl. sugars) (% of dry weight)

<table>
<thead>
<tr>
<th></th>
<th>(FAO, 1999)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDF</td>
<td>75.0 (neutral detergent fiber, total cell wall content)</td>
</tr>
<tr>
<td>ADF</td>
<td>57.5 (acid detergent fiber, NDF less hemicelluloses)</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>17.5 (NDF minus ADG, hemicellulose is a long-chain carbohydrate hydrolyzed by dilute acids into mainly xylose)</td>
</tr>
<tr>
<td>Lignin</td>
<td>11.0 (determined by potassium lignin procedure on ADF residue, oxidizing the lignin)</td>
</tr>
<tr>
<td>Cellulose</td>
<td>42.5 (burning above residue)</td>
</tr>
<tr>
<td>Ash</td>
<td>4.0 (what remains upon burning)</td>
</tr>
</tbody>
</table>

The effects of dietary carbohydrate sources on fish performance have also been studied by a number of authors. Shiau and Lin (1993) studied the effects of starch or fructose on the growth and feed efficiency of *O. niloticus* x *O. aureus* hybrids. They found that starch was better utilized than glucose. In addition, Shiau and Chung (1995) studied the effects of polysaccharides, disaccharides and glucose on the performance of the same species. They found that fish growth rates were as follows: starch > maltose > sucrose > lactose > glucose.
It is clear from the foregoing discussion that tilapia can utilize complex carbohydrates more efficiently than simple sugars. This may explain the poor performance of Nile tilapia fed date pits-based diets in the present study. On the contrary, Anderson et al. (1984) found that *O. niloticus* fed diet containing glucose as the only carbohydrate source grew as well as those fed a diet containing dextrin source, their growth was superior to that of tilapia fed a diet containing starch.

Carbohydrate utilization by fish varies and remains obscure (Shiau and Peng, 1993; Wilson, 1994). Tilapia species have been demonstrated to utilize complex carbohydrates, such as dextrin or starch for growth more readily than simple sugars such as glucose (Shiau and Lin, 1993). In addition, Shiau and Chung (1995) found that tilapia juveniles utilize disaccharides better than glucose but more poorly than starch. This may explain the poor utilization of dates incorporated in diets.

On the contrary of the present study, Al Asgah (1987) studied the possible replacement of wheat bran-barley mixture by date pits in carp feed. He found that partial replacement of up to 75% level improved carp growth. On the other hand, Omar and Nour (1993) found that feed and nutrient utilization of tilapia fed on diets containing different varieties of immature date fruit droppings were similar to corn grain diet. Similarly, Belal and Al-Jasser (1997) determined the effects of replacing dietary starch with pitted date fruit (15, 30 and 45%) in Nile tilapia feed. They found that weight gain, feed conversion, specific growth rate and protein efficiency ratio were improved with increasing date fruit up to 45% as compared with the starch diet (0% date diet). They added that the diet containing 30% date was superior to all other test diets. Body moisture,
crude protein and total ash were gradually increased as the level of date in the feeds was increased, while body lipids were reduced.

Carbohydrate levels in the diets significantly affect tilapia performance. Anderson et al. (1984) found that up to 40% glucose, sucrose, dextrin could be efficiently utilized by *O. niloticus*. The weight gain of *O. niloticus* was improved with the increase in digestible carbohydrate levels from 30% to 40%. The authors concluded that the optimum growth was attained on a diet containing 30% digestible carbohydrate when the dietary protein level was fixed at 35%. Similar results were reported on *T. zillii* which were reported to utilize up to 40% dietary carbohydrate without adverse effects on their growth and feed efficiency (El-Sayed, 1987).

Fish body size affects carbohydrate utilization in tilapia. The present study indicated that smaller fishes (10g) utilize date pits more efficiently than large fish (50g). Similarly, Tung and Shiau (1993) conducted a study to elucidate whether tilapia with two body sizes (4.5g and 0.46g) utilized glucose better than starch. They found that the larger fish gained significantly more body weight and had a better FCR, protein and energy deposition than the small fish when fed a glucose diet. However, weight gain, FCR, Protein and energy deposition of large and smaller fish were similar when the starch diet was fed. Fish fed the starch diet gained more body weight than those fed the glucose diet in both large and small fish. Small fish fed the starch diet had significantly more body lipid than those fed glucose diet. However, large fish had more body lipid than small fish irrespective of dietary carbohydrate source. The authors concluded that these fish utilized starch more efficiently than glucose.
Although, carbohydrates are considered the least expensive form of dietary energy for animals, studies on their utilization and metabolism by fish are limited and need further studies. In the absence of adequate dietary carbohydrates or lipids, fish will utilize protein to meet their energy needs (Cowy and Sargent, 1979). When adequate energy is available the protein will be utilized for growth. Utilization of carbohydrates as an energy source at the expense of protein is referred to as protein-sparing effect of carbohydrates. Protein sparing effect by carbohydrates has been reported by many authors (Shaiu and Peng, 1993; Ali and Al Asghah, 2001). Carbohydrates may also serve as precursors for various metabolic intermediates necessary for growth i.e. nonessential amino acids, nucleic acids and gelatinized starch.

It is well known that herbivorous and omnivorous fish can efficiently utilize dietary carbohydrates, and therefore these fish are cultured practically with diets containing large amount of carbohydrates (Shimeno et al., 1979). Ogino and Chen (1973) indicated that carp can effectively digest and absorb the nutrient regardless of the carbohydrate level in the diet.

The effects of processing of carbohydrate sources on their quality for different animals have been studied with varying results. Hussein et al. (1998) found that treating date pits with sulfuric acid had no significant effect on growth performance and feed utilization of broilers. Date palm materials have been treated to improve their quality. Yousif et al. (1996) found that the ammonia treated date palm leaves and wheat straw were palatable enough to be fed on their own to sheep without any supplementation. However, Ali et al. (1999) removed the fibrous coats of the pits by soaking them in 70% sulfuric acid for 30 min. They found that treated pits did not improve body weight of rats.
The fiber content of date pits is very high and acid treatment only removed the fibrous sheeted date pits. Therefore, leaving date pits in acid for longer time or the use of other treatments might be more effective.

Little information is available on the effects processing of dietary carbohydrate sources on their quality for tilapia. El-Sayed (1991) found that cooking sugar cane bagasse slightly improved its quality for *T. zillii*. Recently, El-Sayed (2002b) studied the effect of fermentation of water hyacinth on its quality for Nile tilapia fingerlings. He found that fermentation improved its quality when it was included in the diets at high levels (20%) while fermentation was not necessary at low hyacinth inclusion levels (10%).

Acid treatment of date pits in the present study did not improve its quality for Nile tilapia at 25 or 50% inclusion level. This is in agreement with Hussein et al. (1998) who found that treating date pits with sulfuric acid had no significant effect on growth performance and feed utilization of broilers.

The supplementation of date pits-based diets with exogenous enzymes in the present study did not result in any improvement in Nile tilapia performance. Similar results were reported on the shrimp, *Litopenaeus vannamei* (Divakaran and Velasco, 1999). This finding is in contrast with the results of El Dahhar (1999) who studied enzyme inclusion for grey mullet, *Liza ramada*. He found that the effect of heat-treated feed and exogenous zymogen on the survival and growth of grey mullet larvae. Heat treatment for 20 min with 4% zymogen gave the best results for larval survival rate and growth. Heat treatment before enzyme addition with increasing enzyme level in the diet could be effective in this regard.
The insignificant effects of exogenous enzymes could be attributed to: 1) enzyme degradation, 2) bad storage, and 3) enzyme lose its effectiveness in fish stomach.

The supplementation of feed of different terrestrial animals with exogenous enzymes has been extensively studied. Supplementing the diets of pigs diets (Medel et al., 2002; Yin et al, 2000 and Gill et al, 2000), for poultry (Viverso et al., 1994; Flores et al., 1994; Yu et al., 1998; Steenfeldt et al., 1998) and for grey mullet, Liza ramada (El Dahher, 1999) with enzymes has resulted in a significant improvements in their performances.

Conclusions:

1) Date pits are not recommended as a carbohydrate source in tilapia fingerlings diets at more than 25% as they are almost entirely simple sugars. However, date pits could be incorporated in fish diets as a natural repartitioning agent for obtaining less-fatty fish as suggested by Yousif et al. (1996).

2) Furthermore, cost-benefit analysis of date pits-based diets should be conducted to test whether they can be incorporated into tilapia diets, and at what inclusion level.

3) Acid treatment of date pits or the supplementation of exogenous enzymes to date pits did not improve their quality for Nile tilapia fingerlings.
References
References


91


Food and Agriculture Organization of the United Nation, FAO (1999) Date palm cultivation, Rome.

Food & Agriculture Organization of the united Nations, FAO (1983). Fish feeds and feeding in developing countries. The ADCP feed development program. ADCP\REP\83\18.


Kuo, H. (1988) progress in genetic improvement of red hybrid Tilapia in Taiwan. Taiwan Fisheries Research Institute Lukang 50510, Chang Hwa, Taiwan, pp. 219-221.


(Oreochromis niloticus X Oreochromis aureus) diets at two protein levels.
Aquaculture, 65 (3-4): 251-261.


Shiau, S.Y., and Huang, S.L. (1990). Influence of varying energy levels with two protein
concentration in diets for hybrid tilapia (Oreochromis niloticus x Oreochromis
aureus) reared in seawater. Aquaculture, 91: 143-152.


Oreochromis niloticus X Oreochromis aureus, Aquaculture. 133: 249-256.

on the utilization of different carbohydrates in tilapia, Oreochromis niloticus X O.

fishmeal with soybean in male tilapia (Oreochromis niloticus x Oreochromis
230-235.

depresses growth in tilapia, Oreochromis niloticus X O. aureus. Aquaculture 179:
439-446.


Soliman, A.K., Jauncey, K. and Roberts, R.J. (1985) Qualitative and quantitative identification of L-gulonolactone oxidase activity in some teleosts, Aquaculture (Bamidgeh), 16, 249.


(Oreochromis niloticus X O. aureus) in intensive culture, Aquaculture, 75: 115.

supplementation of a diet based on barley, and autoclave treatment, on apparent 
digestibility, growth performance and gut morphology of broilers, Animal Feed 

levels in diets for Tilapia nilotica. Nippon Suisan Gakkaishi, 51: 141-146.

Culture of Florida red tilapia in marine cages: the effect of stocking density and 

salinity on growth, feed consumption and conversion in juvenile, monosex male 

Watanabe, W.O., French, K.E., Ellingson, L.J., Wicklund, R.I and Olla, B.L. (1988b) 
Further investigations on the effects of salinity on growth in Florida red tilapia: 
Evidence for the influence of behavior. In: 2nd Int. Symp. on tilapia aquacult. 
Conf. Proc. 15. R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean 
(eds). pp. 525-530.


www.kemin.com/livestock-feed-ingredients/enzymes.shtml


البلطي النيلی (10 جرام) مرتين في اليوم ولمدة 88 يوم. وقد أظهرت النتائج أن المجموعة التي تغذت على علف خالي من نوى التمر (صفر%) قد أعطت أفضل نمو وفضل استفادة من الغذاء مقارنة بباقي المجموعات. كما قل النمو والاستفادة من الغذاء بصورة واضحة مع زيادة مستويات نوى التمر في العلائق. ولكن لم يتأثر البروتين والطاقة ومكونات الجسم تأثيراً كبيراً مستويات نوى التمر كما أن معالجة نوى التمر بالأسواق والحامض أو كليهما معاً لم تحسن من جودة نوى التمر لهذه الأسماك وعلى الرغم من ارتفاع أداء الأسماك التي تغذت على أعلاف محوية على نوى التمر فان انخفاض سعر تكلفة العلف المحلي على نوى التمر مقارنة بالعلف الخالي منه قد يعرض النقص في النمو وكفاءة الغذائية. ولذلك فإن إجلال حوالي 25% من خاللاة القمح بنوى التمر قد يكون ذا جدوى اقتصادية.
الملخص العربي

لقد أجريت دراسة معملية لتقييم استخدام نوى النتمر كمصدر طاقة لإصبعيات و يوافق أسماء البلطي اليني خلال تجارب مثلاً مثاليتين. في التجربة الأولى تم إعداد خمس علاقات متماثلة في الطاقة (450 كيلو كالوري /0.1 جرام) مماثلة للبروتينات (35% بروتين) تحتوي على (0.25، 0.50، 0.75، 1.00) نوى النتمر كإحلال لنخلة القمح (مصدر الطاقة). وقد تم إعداد العالقات وإطعامها بجموعات مزودة من إصبعيات (0.1 جرام) ويوافق (0.5 جرام) البلطي اليني مرتين يوميا ومدة سبعين يوم. يتكون نظام التربيت من أحواض من الفيرجيلاس سعة 70 لترًا متصلة في نظام داعري مغلق وقد أظهرت نتائج الدراسة أن إحلال نوى النتمر (25%) بالنسبة للحجوم من الأسماء اثر تأثيراً سلبياً واضحاً بمعاملات العالقات إلا أن كمية الدهن في جسم الأسماء قد قلة بصورة واضحة في الأسماء الصغيرة التي تم تغذيتها عل علف بحوالي 100% نوى النتمر كما أثبتت هذه التجربة أن إصبعيات البلطي اليني قد استخدمت نوى النتمر بشكل أفضل من الأسماء الناضجة.

في التجربة الثانية تم إعداد ثمان علاقات مماثلة في الطاقة والبروتين تحوي على (0، 25، 50% من نوى النتمر (25، 50% من نوى النتمر المعالج بالحمض و (25، 50%) من نوى النتمر المعالج بإضافة نباتية. ولقد تم تغذية سمك إصبعيات
عزيزي علاء،

أنت تحمل أسلوبًا عالميًا في عالم الفضل.

 llama llama

 ومع تحياتكم،

[Signature]

[Date]
الملخص العربي
استخدام نوى التمر ك مصدر طاقٍ للبرمطي النيلي

(Oreochromis niloticus)

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