Sultan Qaboos University

College of Agricultural and Marine Sciences

ANNUAL RESEARCH REPORT 2006

VOLUME XII

CAMS RESEARCH 2006

FACTS & FIGURES

- **RO 1,357,115 Total Budget**
- **50 Research Projects in Total**
    - **37 Internal Grant Projects (10 awarded in 2006)**
    - **6 Strategic Projects (1 awarded in 2006)**
    - **7 Externally-Funded Projects**
- **82 Refereed Journal Publications**

Annual Research Report
2006

Volume XII

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Foreword

The year 2006 was yet another year of strength in the ability of the College of Agricultural and Marine Sciences to conduct basic and applied research.

During the year under review, 10 internally-funded projects with a total value of RO 75,000 were awarded to CAMS. The College was also awarded a strategic research project from His Majesty's Strategic Research Fund to the value of RO 95,000. Outputs from the various research projects continues to increase with a total of 82 refereed journal papers in 2006.

The College continues to maintain strong links with reputable international organizations with the aim of maintaining high research quality and standards.

The MSc program is now in its 11th year and represents an important avenue to develop and enhance our national capacity for research.

The research accomplishments over the past year are attributable to the hard work and contributions of researchers, staff and students. Sincere gratitude goes to the Research Committee, College Administration, faculty, staff and students. Our accomplishments during the year under review would not be possible without the support of the Deputy Vice Chancellor for Postgraduate Studies and Research and the University Administration, and for that we are thankful.

Nadiya Abubakar Al-Saady, Ph.D.
Assistant Dean for Postgraduate Studies and Research

Research Committee

Dr. Nadiya Abubakar Al Saady, *Chair*

Dr. Houcine Boughanmi

Dr. Linus Opara

Dr. Isam Kadim

Dr. Rashid Al Yahyai

Dr. Amanat Ali

Dr. Michel Claereboudt

Dr. Anvar Kacimov

The Year in Review

Introduction

Continuous investment in research infrastructure through research projects gives CAMS a solid foundation to further enhance its ability to conduct research to address the national development goals of Oman. The overall strategic goal of our research activities is to increase the efficiency of agriculture, food systems, animal production, animal and human health and marine sciences and fisheries. CAMS is also committed to transferring knowledge and skills to the broader community through its research and graduate programs.

Research Projects and Budgets

For the year 2006, the CAMS total research budget was RO 1,357,115 (Table 1).

Nine internal grant projects were completed (Table 2), while 10 were awarded (Table 3). (Abstracts of research projects awarded in 2006 can be found on pages 48 to 59). There were also 18 continuing internal grant projects (Table 4).

Table 5 shows one completed research and development project which was funded by His Majesty's Strategic Research Fund. There was also one new strategic research project which was awarded in 2006 (Table 6) (abstract of strategic research project awarded in 2006 is on pages 61 to 62), while 4 were continuing (Table 7).

Two externally-funded research and development projects were completed in 2006 (Table 8), 4 are continuing (Table 9), while one was terminated (Table 10).

Table 1. Summary of research and development projects held by the College over 2000-2006.

Source	Number of Projects	Budget (RO)	Total Budget (RO)
Internally-funded (SQU) projects			248,825
Completed in 2006	9	53,770	
Awarded in 2006	10	75,000	
Continuing	18	120,055	
His Majesty's strategic research fund			570,850
Completed in 2006	1	87,500	
Awarded in 2006	1	95,000	
Continuing	4	388,350	
Externally-funded projects			537,440
Completed in 2006	2	66,820	
Continuing	4	458,620	
Terminated	1	12,000	
Total			**1,357,115**

Table 2. Internally-funded research and development projects completed in 2006.

#	Title of Research	Principal Investigator	Grant Dates (start-end)	Amount (RO)
1.	Development of a solar thermal-powered pumping system	***S. Al-Rawahy***	2000-2002	8,400
2.	Ripening profile of semi hard standard goat's milk cheese	***N. Guizani***	2003-2005	6,000
3.	Response of chickpea (*Cicer arietinum* L.) to salinity stress	***H. Esechie***	2003-2005	4,400
4.	Fractionation of heavy metals in calcareous soils amended with sewage sludge	***M. Al-Wardy***	2003-2005	4,450
5.	Methodology to identify redundant piezo-meters and locations for new piezometers in hydro-geologic basins	***S. Prathapar***	2004-2006	5,600
6.	Biometrics of the Indian oil sardine *Sardinella longiceps* val. along the coast of Oman	***S. Al-Jufaili***	2004-2006	3,600
7.	Seasonal study of dissolved organic matter in relation to phytoplankton in the Gulf of Oman	***A.R. Al-Azri***	2004-2006	7,550
8.	Salinity as a direct and indirect pre-disposing factor for damping off disease in greenhouse cucumber production	***M. Deadman***	2004-2006	9,520
9.	Integrated small-scale tilapia farming in Oman	***S. Goddard***	2004-2006	4,250
Total				**53,770**

Table 3. Internally-funded research and development projects awarded in 2006.

#	Title of Research	Principal Investigator	Grant Dates (start-end)	Amount (RO)
1.	The effect of low levels of dietary cobalt on select parameters of the specific and non-specific immune responses of Omani goats	***E. Johnson***	2006-2008	10,200
2.	Bioavailability of iron in various types of meats in the Sultanate of Oman	***I. Kadim***	2006-2008	10,000
3.	Molecular investigation of lime Witches' Broom phytoplasma in Oman	***N. Al-Saady***	2006-2008	10,200
4.	Collection and evaluation of native and exotic germplasm of important crops of Oman	***A. Al-Maskry***	2006-2008	8,000
5.	Mango rootstock evaluation, conser-vation and use in Sultanate of Oman	***M. Deadman***	2006-2008	7,100
6.	Screening of lettuce cultivars for production under different shade levels	***F. Al-Said***	2006-2008	4,720
7.	Physiological responses of date palm to various levels of water stress	***R. Al-Yahyai***	2006-2008	4,480
8.	Comparative studies of size-fractionated phytoplankton primary productivity and bacterial biomass and production in Bandar Khayran Bay, Gulf of Oman and Masirah Island, Arabian Sea	***S.I. Ahmed***	2006-2008	11,500
9.	Effect of manure amendment with varying C:N ratios on N minerali-zation in soil	***S. Ismaily***	2006-2008	4,400
10.	Design and construction of green-houses for arid regions	***Y. Al-Mulla***	2006-2008	4,400
Total				**75,000**

Table 4. Continuing internally-funded research and development projects.

#	Title of Research	Principal Investigator	Grant Dates (start-end)	Amount (RO)
1.	Development and testing of a computer controlled, cyclic misted forced ventilation system for cooling dairy cows	***L. Opara/ I. Haffar***	2002-2004 (Extended to end of Dec '07)	4,000
2.	Solute transport in porous media: physical, analytical and numerical modeling	***S. Al-Jabri***	2002-2004 (Extended)	6,150
3.	Quantification, prediction, and reduc-tion of postharvest losses of fresh food crops in Oman	***L. Opara***	2004-2006 (Extended to end of June '07)	7,500
4.	Utilization of power and machinery in arid agriculture	***L. Opara/ D. Ampratwum***	2004-2006 (Extended to end of June '07)	2,650
5.	Nutritional evaluation of traditional Omani meals-studies on the chemical composi-tion, glycemic responses and atherogenic factors	***A. Ali***	2004-2006 (Extended to end of May '07))	7,700
6.	Development and optimization of genetic transformation procedures for Omani Banana varieties	***N. Al-Saady***	2004-2006 (Extended to end of June '07)	8,280
7.	Studies of foodweb interactions and carbon flow in the mangrove ecosystem of the Sultanate of Oman	***S.I. Ahmed***	2004-2006	9,450
8.	Use of various levels of fish silage for feeding Omani sheep and goats	***O. Gaafar***	2005-2007	6,000
9.	Caprine Arthritis Encephalitis Virus (CAEV): a pathological and serological study	***M. Tageldin***	2005-2007	10,325
10.	Evaluation of alternative cheap local energy and protein sources for feeding Omani and commercial poultry strains in the Sultanate of Oman	***W. Al-Marzooqi***	2005-2007	10,000
11.	Effects of drying methods on functionality of garlic powder	***S. Rahman***	2005-2007	7,200
12.	Analyzing the implications of the new GCC custom union on trade, industry compete-tiveness and economic welfare of GCC countries	***H. Boughanmi***	2005-2007	4,800
14.	Water markets in aflaj systems, economic efficiency and institutions	***S. Zekri***	2005-2007	5,000

Table 4. . .

#	Title of Research	Principal Investigator	Grant Dates (start-end)	Amount (RO)
15.	Economic and institutional aspects of King-fish management	***H. Kotagama***	2005-2007	5,000
16.	Biodiversity and community structure of hard-substrate littoral communities in the Sultanate of Oman	***M. Claereboudt***	2005-2007	10,500
17.	Nausea and vomiting in pregnancy, maternal nutrition and pregnancy outcome	***B. Al-Rasasi***	2005-2007	3,600
18.	Development of salt and drought tolerant vegetable crops in Oman	***A.J. Khan***	2005-2007	11,900
Total				**120,055**

His Majesty's Strategic Research Projects

In 2006, CAMS was awarded funding for a strategic research project for the sum of R.O. 95,000 through His Majesty's Strategic Research Fund. The project will include work on management of salt-affected soils and water for sustainable agriculture. Two HM projects on the use for seawater to cool greenhouses and evaluation of greywater reuse were completed in 2006.

Table 5. His Majesty's strategic-funded research projects completed in 2006.

#	Title of Research	Principal Investigator	Date Granted	Amount (RO)
1.	Seawater greenhouse development for arid climates: An innovative approach for water desalination and crop production	***S. Sablani***	2002	87,500
Total				**87,500**

Table 6. His Majesty's strategic-funded research projects awarded in 2006.

#	Title of Research	Principal Investigator	Date Granted	Amount (RO)
1.	Management of Salt-Affected Soils and Water for Sustainable Agriculture	***S. Al-Rawahy***	2006	95,000
Total				**95,000**

Table 7. Continuing projects funded through His Majesty's strategic research fund from 2004-2006.

#	Title of Research	Principal Investigator	Date Granted	Amount (RO)
1.	Improving production of vegetable crops by development stress tolerant germplasm and farming systems research	***I. Khan / F. Al Said***	2004	74,800
2.	Value-added marine raw materials and health	***B. Soussi***	2005	150,000
3.	Postharvest technology to reduce losses and improve quality and supply of Omani local fresh food produce	***L. Opara***	2005	65,950
4.	Evaluation of greywater reuse potential for sustainable water resources management in Oman-Phase 1	***S. Prathapar***	2003 (Extended to end of April 2007)	97,600
Total				**388,350**

Externally-Funded Research Projects

Externally-funded projects completed in 2006 are summarized in Table 8 and continuing projects are summarized in Table 9. A total of 2 projects were completed in 2006, while 4 were on-going. The projects involved collaboration with UAEU, MAF, PD0 and UNESCO.

Table 8. Externally-funded research and development projects completed in 2006.

#	Title of Research	Grantee(s)	Agency	Date Started	Amount (RO)
1.	Study of pesticide resistance and residue problems in Omani and UAE vegetable production	***F. Talukder***	United Arab Emirates University (UAEU)	2004	6,475
2.	Modeling of groundwater in two selected coastal aquifers of UAE and Oman as a precursor for water resources management	***A. Kacimov***	UAEU	2003	60,345
Total					**66,820**

Table 9. On-going externally-funded research and development projects.

#	Title of Research	Grantee(s)	Agency	Date Started	Amount (RO)
1.	An assessment of the grouper fishery of Oman	***J. McIlwain*** ***H. Al-Oufi***	MAF, Oman	2003	99,220
2.	Mechanical profile control performance of elastomer seals	***A. Kacimov*** (with College of Engineering)	PDO, Oman	2005	325,000
3.	Pesticide resistance and residue problems in Omani and UAE vegetable production. Phase II: Solution through rapid and molecular detection techniques & farmers awareness	***F. Talukder***	UAEU	2006	24,750
4.	Insecticide resistance in major agricultural insect pests in Oman: Monitoring and management strategies	***F. Talukder***	UNESCO	2006	9,650
Total					**458,620**

Table 10. Terminated* (in Summer of 2006) externally-funded research and development project.

#	Title of Research	Grantee(s)	Agency	Date Started	Amount (RO)
1.	Spirulina culture using brine water from desalination plants	***J. Perret*** ***A. Mothershaw*** ***M. Claereboudt***	MEDRC, Oman	2001	12,000
Total					**12,000**

**PI - resigned.*

Other Significant Activities

On May 2nd, CAMS celebrated the annual Research Day which was inaugurated by Dean Anton Mclachlan while the ADPGSR gave an overview of the research activities at CAMS. Prof. Bassam Soussi and Dr. Linus U. Opara gave an update of their strategic projects. Drs. Slim Zekri, Isam Kadim, Farid Talukder, Amanat Ali, Veera Sarma, Johan Perret, Houcine Boughanmi, Osman Gaafar and Ann Mothershaw presented on their research activites. The progress of other projects was presented in a poster session. Abstracts of the oral and posters presentations are presented in pages 14 to 37.

On May 30th, CAMS organized a Strategic Research Retreat which was attended by the faculty members. The ADPGSR welcomed the faculty and thanked them for their active participation in research. The sessions then commenced focusing on the three research themes. Several proposals for strategic research were presented as shown below.

Presentor	Title
Dr Andrew Palfreman	The valuation of the marine environment to Oman
Dr Osman Mahgoub	The evaluation and improvement of the poultry industry in the Sultanate of Oman
Dr Farid Talukder	Development of management strategies for pesticide resistance and pesticide residue problems in Omani agriculture
Dr Nadiya Al-Saady	Conservation and utilization of plant and animal genetic resources in Oman

The sessions ended with a hearty discussion.

Two international conferences were held in the College in 2006 as follows:

Host Dept/Agency	Title / Date of the Conference	Conference Chair
Agricultural Economics & Rural Studies/ SQU Water Research Center/ Ministry of Regional Municipalities, Environment & Water Resources	Economic Incentives and Water Demand Management 18-22 March 2006	Dr. Slim Zekri
Crop Sciences	Date Palm Production and Processing Technology 09-11 May 2006	Dr. Fahad Al-Julanda Al-Said

The main objective of the conference on economic incentives and water demand management was to bring together scientists, experts and decision-makers working on the water sector from developed and less-developed countries to learn from existing working experiences in the field of economic incentives and demand side management of water.

The date palm production and processing technology conference was the outcome of an HM strategic project on the improvement of date palm production and dates quality in the Sultanate of Oman.

ABSTRACTS
(Oral & Poster Presentations)

Oral Presentations

Value-Added in Marine Raw Materials and Health

Bassam Soussi
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His Majesty's Strategic Research Trust Fund

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This project aims to establish an integrated research program in value-added seafood/marine raw materials for health. Quality, safety, human nutrition issues are addressed as well as the evaluation of novel candidate substances and their mechanisms of action.

The beneficial health effects from a fish-rich diet indicated in epidemiological studies point out the involvement of omega-3 free fatty acids (n-3 PUFA). However, the mechanisms remain unknown and aqueous compounds in the fish might possibly also be involved. Utilizing marine bioactive compounds for value added food or functional foods can raise the status of the fish industry, but more knowledge is needed on mechanisms of action and oxidative stabilization. We aim at (i) developing new natural antioxidative strategies for marine bioactive substances and (ii) further evaluating the role of marine antioxidants in vivo.

The effects of dietary oils on the n-3 PUFA content of two species of farmed and marine fish will be examined. The fish produced with increased n-3 PUFA concentrations along with marine fish will be studied in animal models and clinical trials with human volunteers in Oman. Quality issues will be addressed by innovative post-harvest handling, packaging and storage conditions to improve the quality of fresh and frozen fish.

An extra dimension will be provided by studying algae and a variety of marine invertebrate organisms from Omani habitats. Extraction, processing and identification of compounds will be carried out.

This multidisciplinary research project will be performed at Sultan Qaboos University involving the Colleges of Agriculture and Marine Sciences and Medicine and Health Sciences and the Ministry of Agriculture and Fisheries. A strong and established international collaboration will facilitate technology transfer and sharing of scientific results and expertise. The project links medical sciences, food science and nutrition with seafood/ marine biotechnology. Parts of the work will be conducted in collaboration with the industry, locally and abroad.

The project at large aims at studying bioactive compounds in marine raw materials from molecule to man with focus on health. Traditional and new tools for measurements will be used. In vivo studies will be based on mouse/rat models combined with state-of-the-art whole body high resolution MRS/MRI investigations.

This proposal consists of eight work packages:

1. Evaluation and stabilization of tentatively identified bioactive compounds in fish.
2. Effect of marine antioxidants on cardiac energy metabolism in the murine heart, studied by MR.
3. Effects of kingfish oil on atherogenic lipid profile and glycemic status in rats.
4. Dietary strategies for increasing the content of n-3 PUFA in farmed freshwater and marine fish.
5. Improvement of fish quality by maintaining its functional components and controlling its anti-nutritional factors.
6. Investigation of seaweed ingredients in adding value to indigenous marine products.
7. Extraction and screening of bioactive compounds from invertebrate organisms around coral reef sites in Oman.
8. Effect of fish and fish oil consumption on blood lipid profile, blood pressure and endothelial function in a selected population in Oman.

Impact

- Identification of additional bioactive components in fish and other marine species for functional foods and nutraceuticals will create business opportunities.
- Production of high quality safe seafood will contribute to better health and well being.
- Illumination of the mechanisms behind the role of fish consumption in disease prevention will lead to better dietary recommendations.

Postharvest Technology of Omani Fresh Produce - A Strategic Research and Development Program

Linus U. Opara
Principal Investigator, Grant No. SR/AGR/BIOR/05/01
His Majesty's Strategic Research Trust Fund

Department of Soils, Water and Agricultural Engineering
Agricultural Experiment Station (AES)
College of Agricultural and Marine Sciences
Sultan Qaboos University

The arid environment in Oman and similar countries in the Gulf region presents unique environmental and resource management challenges for profitable agricultural production and maintenance of fresh produce quality. Consequently, Oman is a net food importer. However, the government has invested heavily in modern production inputs (such irrigation, machinery, improved seeds, fertilizers) to assist farmers and agribusiness entrepreneurs as part of the overall national food security strategy and economic diversification. Unfortunately, poor product quality, high incidence of losses and unreliable supply are some of the problems limiting the economic potential of Omani agriculture. In many product categories, local produce cannot compete favorably with imported produce that often have higher quality attributes, even though the imported produce are usually sold at higher prices.

The aim of postharvest technology application is to reduce the incidence of product losses, maintain product quality and traceability, and enhance overall business profitability. Indeed, there is mounting literature evidence that investments in postharvest technology and improved marketing facilities result in higher or comparable internal rates of return (IRR) than investments in on-farm production inputs alone (Goletti et al., 2000).

Following a series of stakeholder consultations in the Omani agricultural sector in 2003-2004, we initiated a comprehensive research and development program on postharvest technology to reduce the incidence of losses and improve the quality and supply of Omani fresh produce. In this presentation, we outline the components of the research program and highlight the achievements made during the past year. Overall, considerable progress has been achieved in establishing basic research infrastructure and training Omani personnel on the techniques and procedures of postharvest technology research. We conclude this presentation with examples of specific research outputs accomplished to date and outline the strategies for research program implementation during the next two years.

Demand Elasticity of Water in Community Managed Irrigation Systems in Oman

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Market, price and quantity based approaches vis-à-vis legal, command and control approaches are being widely adopted in natural resource and environmental management since the 1980s. Experience in adopting markets in managing irrigation water resources too is emerging. It has been argued that markets are ineffective in managing the demand for irrigation water due to very low own price elasticity. Most of these studies are based on mathematical models simulating water markets and not based on observed prices and quantities in real water markets as such data are rarely available. In Oman, perhaps in response to the extreme scarcity of water, elaborate water demand management institutions emulating markets have evolved. and have been used over centuries. Quantitative water entitlements are traded, based on prices through a community auction. The traded quantities of water and related prices have been recorded. This study uses these unique data to estimate the own price elasticity of irrigation water. A log function on quantity and price of irrigation water is used with dummy variables on time and type of irrigation system. The own price elasticity varies from -0.10 to -0.37 depending on the different specification of the econometric model. These estimates are higher than most estimates given in past studies indicating the efficacy of the indigenous market based irrigation water management institution adopted in Oman.

Relationship Between Ascorbic Acid Supplementation in Drinking Water and Heat Stress on Poultry Maintained in Open-sided Housing

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The efficacy of ascorbic acid treatments of drinking water for performance, carcass and meat quality characteristics in broiler chickens reared in closed and open-sided houses was studied in two seasons: cool season (January-February) and hot season (August-September). Four hundred and thirty-two 1-d-old chicks (Cobb500 strain) were housed in closed and open-sided poultry houses for each season. All the birds were maintained under 23hrs light and 1 hr dark cycle and consumed water and feed ad libitum.

The ambient temperatures inside the poultry houses were 25.8^{o}C (closed), 28.7^{o}C (open-sided), 31.6^{o}C (closed), and 37.4^{o}C (open-sided) for cool and hot seasons, respectively. Broilers in both houses were randomly subjected into four drinking water treatments: 1. un-supplemented water (control); 2. 100-ppm ascorbic acid supplemented water; 3. 200-ppm ascorbic acid supplemented water; and 4. 300-ppm ascorbic acid supplemented water. Each treatment group was replicated in six pens containing 54 birds. All birds were provided ad libitum access to feed and water through to 42 days of age. Feed intake, growth rate, feed conversion ratio, and rectal temperatures were recorded weekly (1-42 days of age).

The results indicated that ascorbic acid supplementation at 200-ppm and greater was an effective method for reducing rectal temperature of broiler chickens during hot season. Open-sided house depressed ($P<0.05$) weight gain, feed intake and feed conversion ratio during hot season due to high ambient temperatures. In comparison with the un-supplemented water, feed intake, weight gain and feed conversion ratio were improved by 5-7%, 7.0-10.0% and 2-3% (cool season), 7-9%, 10-11%, and 4-5% (hot season). Ascorbic acid at level 200-ppm significantly increased ($P<0.05$) feed intake, weight gain and feed conversion ratio more than un-supplemented water group during the cool season, while 300-ppm increased significantly ($P<0.05$) broiler performance including feed intake, gain and feed efficiency and growth rate more than un-supplemented water groups during hot season.

Pesticide Use Patterns in Omani and UAE Vegetable Production

F.A. Talukder [1], W. Kaakeh [2], M.L. Deadman [1], S.A. Al-Jabri [3], A. Al-Saadi [1], A.A. Al-Raeesi [1], J.H. Al Dahmani [2], M. Maraqa [4], H. Al Hasani [5] and L. Al-Subhi [5]

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To combat the pesticide resistance and residue problems in Oman and UAE, the joint SQU – UAE research project [CL/SQU-UAEU/04/01] was carried out in 40 different vegetables growing farms in the Al-Batinah, Oman and Al -Ain, U.A.E., with different objectives, including to determine the current pattern of pesticide uses in vegetable production in both countries.

The surveys found that all Omani and UAE vegetable farms use pesticides for crop protection. Among the most commonly used pesticides, around 29 insecticides, 16 fungicides and 3 herbicides were recorded, as used by the Omani vegetable farmers. Our results showed that around 55% Omani farms used routine application of pesticides, irrespective of the pest presence, where as in UAE, most farmers start to spray pesticides, when there was a 6-20% infestation. The tested insect and disease pests were found as resistant to different pesticides, which are currently being used in both countries.

Nutritional Quality and Glycemic Index of Traditional Omani Foods

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Glycemic Index (GI) of foods is a useful tool for elucidating the effects of carbohydrate rich foods on postprandial blood glucose response and has shown its significance as a useful nutrition concept for classifying the carbohydrates. The available evidence to date suggests that GI will be an important factor in the planning and conduct of future dietary prevention research in relation to chronic diseases. The data from the epidemiological, case control, and some randomized control studies suggests a positive role of the glycemic index of foods in the prevention and management of chronic diseases. Diets containing high glycemic index foods have been linked with an increased risk of developing diabetes, cardiovascular diseases and certain cancers. The research conducted under this project not only provides information on the chemical composition and nutritional quality of some traditional Omani foods but also determines their glycemic index in human volunteers to rank them as low, medium and high GI foods. Fifteen different types of breads and some traditional meals, commonly consumed by Omani people, have so far been analyzed for their chemical composition and nutritional quality. Animal model studies have also been planned to determine the impact of these low, medium and high glycemic index foods in relation to chronic diseases. The results of this study will help in developing the appropriate dietary management strategies utilizing the concept of GI of foods in reducing the risk of chronic diseases.

Variability of Chlorophyll-a in the Arabian Sea Derived from SeaWiFS

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The distribution of the chlorophyll-a concentration (chl-a) on sea surface is the most striking feature of ocean color remote sensing. The southwest monsoon and the northeast monsoon drive the observed variability in chl-a concentration. In the Arabian Sea the variability of chl-a, as derived from the SeaWiFS ocean color images, shows anomalously low concentration while in the equatorial Indian Ocean it is just the opposite during late 1997 through early 1998. The winter phytoplankton bloom in the northern Arabian Sea was absent during 1997 winter. The spectral analysis of chl-a from a few locations showed that the annual signal was dominant in the areas affected by only one of the two monsoons. On the other hand, the semiannual signal was predominant in the areas affected by both the monsoons. An empirical model incorporating the annual and semiannual amplitude and phase of chl-a concentration showed that the ratio of the standard deviations of SeaWiFS to modeled chl-a varied between 0.60 and 0.89, indicating reasonable degree of predictability of chl-a variability in this region.

Keywords: SeaWiFS, Arabian Sea, Indian Ocean, Chlorophyll-a, Interannual variability, Empirical model.

Seawater Greenhouse Development for Arid Climate
Strategic Project: SR/AGR/BIOR/02/01

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The Seawater Greenhouse (SWGH) is a unique concept which combines natural processes and simple construction techniques to provide a sustainable solution to one of the world's greatest needs: water for agriculture. By cooling the air with saline water the water consumption can be reduced up to 80% compared to standard greenhouse operation. The cool and humidified air creates a growing environment that substantially reduces the amount of water required by plants. In addition, , fresh water is produced by condensing the humidified air at the back of the greenhouse using relatively cold water coming from the front evaporator. This source of fresh water can be used to supplement the irrigation needs. Results of environmental conditions outside/inside the SWGH are presented and compared to two commercial greenhouses in Oman. In addition, fresh water production and use in the greenhouse is compared to modeling results.

The Effects of Multilateral and Regional Trade Liberalization on Agriculture: The Case of the Gulf Cooperation Council (GCC) Countries

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The GCC countries have been engaged in the last few years in various trade arrangements to liberalize trade and eventually enhance economic growth and social welfare. More recently, the GCC countries transformed their de facto free trade area into a customs union with a common external tariff vis-a- vis the rest of the world. The objective of this paper is to analyze the effects of various trade liberalization scenarios on the GCC countries economy with a particular focus on the agricultural sector. The analysis is intended to provide policy makers involved in regional and WTO negotiations insight into the likely economy-wide and sectoral effects of eliminating tariffs and non tariff trade barriers. The analysis uses the World Trade Simulation Model (WTSM), a computable partial equilibrium and trade focused "price elasticities" model, to solve simultaneously for the equilibrium prices, import and export values and the exchange rate. Results show that under all the trade liberalization scenarios, the economic effects on the GCC region in terms of trade and economic welfare will be positive. However, multilateral trade liberalization covering all the goods offers the greatest benefit to the GCC economies. Also, the study finds that changes in economic welfare are much higher under liberalization process covering all the sectors rather than liberalization covering only the agricultural sector. The effects of multilateral trade liberalization on domestic prices will depend on the type of commodity, the world price change and the initial level of protection. This research provides general directions on the effects of trade liberalization on the GCC economy. These effects are sensitive to the assumptions inherent to the partial equilibrium nature of the model. Further research is needed to improve the robustness of the results by incorporating new data and more precise parameters, but also by taking into consideration some aspects of recent trade reforms that GCC has engaged in at the regional and international levels.

Keywords: GCC, trade liberalization, world trade simulation model, agriculture, welfare effects, GAMS.

Use of Enzyme Linked ImmunoSorbent Assay (ELISA) for Detection of Antibiotic and Anabolic Residues in Local and Imported Goat and Sheep Meat in Oman

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Meat samples were collected from Omani and Somali goats and from Australian and Somali sheep at random at Baushar Municipality slaughterhouse, Muscat during April -May 2004. ELISA kits specific for antibiotics and anabolic agents were used to detect residues in the meat. Generally, Meat samples contained various levels of residues of antibiotic and anabolic agents tested with the exception of Sulphamethazene. Tetracycline levels ranged between 44-53 ppb/kg (mean 49.8); Streptomycin ranged between 0-20 ppb/kg (mean 11); Chloramphenicol ranged between 0.0-0.08 (mean 0.02). Anabolic agent residues in meat ranged between 0-35, 0-0.05 and 0-016 for Oestradiol 17β, testosterone and trenbolon respectively. However, levels of these residues were below the international allowable levels set by the German Residue Control Plan (GRCP) and the European Union (EU). Meat from the Omani goat had low levels of antibiotic and anabolic agents compared to other animals, which renders it healthy and safe for consumers. The levels of antibiotic and anabolic residues tended to be lowest in Australian sheep meat and highest in Somali goat meat. This indicates that these animals may have been treated shortly before shipping or after arrival in the country and had been slaughtered before the withdrawal period of the drug expired. Generally, goats had higher levels of antibiotic and anabolic residues than sheep with the difference being significant for tetracycline. This difference was mainly due to the higher levels of these agents in the Somali goat meat. This study indicated that sheep and goat meat sold in Oman generally contains some residues of antibiotic and anabolic agents. Although the levels were within the allowable limits, their presence may still be regarded as a health hazard as they may cause allergic reactions or produce drug-tolerant bacteria in humans. More care is needed to monitor importation regulations of animals intended for human consumption.

The Influence of Storage Temperature on the Number and Type of Bacteria on Poultry Meat on Sale in Muscat

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During the last few decades the incidence of food borne illnesses caused by microbial contamination has increased. There has also been a rise in the number of cases of diseases caused by bacteria demonstrating resistance to therapeutic drugs. During the last few years, consumption of poultry products has increased significantly as a consequence of public awareness of the health problems associated with eating red meat. The intrinsic properties of meat confer a high risk for growth of microbial contaminants. It is the role of government authorities and inspection systems to ensure that foods provided to customers are both safe and of high quality. To do this control systems must be in place during food production, processing and storage. One of the most convenient methods to inhibit bacterial growth is to maintain products at low temperatures. The aim of this project was to determine the microbial quality of poultry products on sale in Muscat and the effect of storage temperature on the total counts and the frequency of contamination with specified pathogens. A total of 196 poultry samples previously stored at different temperatures were analyzed. All samples met the Omani standards for total aerobic plate counts. The bacterial plate counts and coliform levels of frozen samples were significantly lower than those of fresh or chilled products. Potential pathogens including Staphylococcus aureus, Salmonella spp. and E. coli were detected. All of the isolates were resistant to at least one antibiotic.

Poster Presentations

Feasibility of Individual Tradable Quotas (ITQ) in Managing Omani Fisheries

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It is expected that fisheries sector would contribute 2% to the Gross National Product of Oman by year 2020 in contrast to its contribution of 0.6% in year 2000. In order to achieve this target and to ensure sustainability of the sector, investments need to be done to improve the quantity and quality of fish harvests and conducted strategies. Omani fisheries management, as in most other countries has been managed by regulatory legislation. In recognition of the ineffectiveness of regulatory management, in the past two decades, several countries have shifted to incentive (market) based management. ITQ is an incentive based management approach in which fishermen are provided transferable/ tradable rights to fish a stipulated quota of the total allowable harvest. Empirical evidence reports the success of ITQs in terms of sustaining the fish harvest, reducing over-capitalization in both fishing and processing, fish market improvements, etc. Problems relating to fairness in initial allocation of quotas, possibility of monopolization, alienating the traditional small fisherman etc have also been reported.

In this study the legal feasibility of introducing ITQ to the management of Omani fisheries has been analyzed. For ITQs to be feasible, legislation should allow the possibility of providing transferable rights to fish a specified quota to individual fishermen and also specifying the total allowable catch. The fisheries act (Ministerial Decree Number 3/82) though has been drafted to support regulatory management, it allows for providing rights to fish (in the form of license that could specify quantities) and in defining the total allowable catch. However the act does not allow for transferring/ trading the license. The technical social and economic feasibilities of introducing ITQs for Omani fisheries management are being analyzed.

Market Potential for Ready to Eat Fish Products in Oman

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The objective of this study is to evaluate consumers' preferences for value added fish products in Oman and identify the most important attributes that are preferred by consumers. Such information is of value to the fish processing companies that are looking for profitable business opportunities in local or international niche markets. The study uses a conjoint analysis method to estimate consumer total utility for value-added fish products on the basis of four attributes: form of the product, package size, method of cooking and the price. A sample of 200 consumers is selected in 4 major supermarkets in the Muscat region to conduct the conjoint experiment. Results of the conjoint analysis show that the most important attribute in the purchasing decision of the average consumer is the cooking method, which contributes 79% to the average overall preference, whereas the least important attribute is the price contributing only 0.34% to overall preference. The most preferred product is a finger or nugget fish form formulated for frying and packaged in a small package, whereas the least preferred products consist of the burger form formulated for microwaving and packaged in large or medium packages. Segmentation of the fish value added market according to nationality showed that there is no significant difference between Omanis and non Omanis preference structure.

Keywords: Conjoint method, consumer preferences, fish value-added products, part-worth utilities.

Evaluation of Alternative Cheap Local Energy and Protein Sources for Feeding Omani and Commercial Poultry Strains in the Sultanate of Oman

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The main objective of this study was to assess the nutritional value of different sources of energy and protein available in the Sultanate of Oman using commercial and Omani poultry strains. Sixteen experimental diets, representing 11 samples of cereals (five- varieties wheat, four barley varieties and two sorghum varieties),and sample of plant protein meal (soybean meal),three sample of animal proteins (fish meal, dry sardines and fish silage) and one sample of pods of legume trees (*Prosodies spp.*) were evaluated using six replicates of eight birds per cage at 21 day of age. Cages were located in an environmentally controlled room maintained under conditions suitable for birds at this age with a photo-period of 23h in every 24h. Diets and water were offered on *ad libitum* basis. On the fourth day after the adaptation to the experimental diets, feed troughs were removed from every cage for 1 h and then reintroduced for 2 h. The birds were killed for sampling of ileal digesta, from Meckel's diverticulum to the ileal-caecal-colonic injunction. The digesta samples were collected in plastic beakers and frozen prior to being freeze-dried. Preliminarily results of the chemical analysis show significant differences between cereals, plant and animal proteins. High crude protein content was observed in fish meal, sardine fish, fish silage and soybean meal than in wheat, barley and sorghum varieties (66.8, 65.5, 70.4, 48.6, 14.1, 13.3 and 11.02 g % dm, respectively). Cereals, in general, had higher nitrogen free extract (NFE). The range of NFE in wheat, barley and sorghum varieties was from 78.38-80.25 g % DM; 74.70-75.81 g % DM and 79.74-81.95 g % DM; respectively. Lower fat content was observed in cereals (1.18-3.19 g % DM) and plant protein sources (2.0-2.18 g % DM) than in animal protein sources (4.5-10.90 g % DM). Accurate diet formulation for chicken requires information on digestible value than gross nutrients of dietary ingredients, therefore, the digestible nutrients are under investigation.

Caprine Arthritis Encephalitis Virus (CAEV). A Pathological Study

(Project No.: IG/AGR/ANSC/05/02)

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Caprine arthritis encephalitis virus (CAEV), a lentivirus of the Retroviridae family. Members of this family are pathogens of humans (HIV), non-human primates (SIV) , domestic and wild animals. Caprine arthritis encephalitis is a chronic disease of goats characterized by inflammatory lesions in several organ systems including, brain, lungs, joints and mammary glands.
Histopathological study was carried out on lung samples. They were collected from slaughtered indigenous goats (6-18 months). Specimens were fixed in 10 % buffered- formalin, processed, sectioned and stained with H&E and special Stains. The histopathological lesions were characterized by interstitial pneumonia, peribronchial, perivsacular and or/ parenchymal lymphocytic infiltration or lymphoid nodules with or without germinal centers. The lymphoid follicles often compressed bronchiolar lumens. Dense fibrosis in the interstitial, interlobular, peribronchial and perivsacular areas had been observed. These lesions were detected in the lungs of clinically healthy animals and no macropthological alterations were observed in the organs.

Salinity and *Pythium aphanidermatum*- Induced Damping-off Disease of Greenhouse Cucumbers in Oman

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Salinity and disease are, respectively, the two most important biotic and abiotic constraints to greenhouse crop production in Oman. Sea water intrusion following excessive groundwater extraction for agricultural production has led to a general increase in the salinity levels of irrigation water used across much of northern Oman. Surveys of the EC levels of irrigation water used in greenhouses across the region show that "hot spots" of high salinity occur within well defined areas. According to published tolerances of cucumber to salinity, over 10% of farms with greenhouses in some areas have EC levels at which crop production becomes marginal as yields are reduced. Anecdotal evidence had suggested that farms with high salinity levels suffered proportionately higher levels of damping-off disease caused by *Pythium aphanidermatum*. Detailed investigations have indicated that levels of salinity that compromise crop growth have no effect on the ability of *P. aphanidermatum* to grow *in vitro* or *in vivo*. In agar prepared with saline irrigation water, the pathogen grew as well in as agar prepared with distilled water, even when the salinity level exceeds that at which cucumber production is untenable. Similarly, in sand culture, *P. aphanidermatum* grew and colonized radish seeds even in the presence of highly saline water.

Development and Optimization of Genetic Transformation Procedures for Omani Banana Varieties

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Developing and optimizing the transformation of banana is important since banana is one of the major crops grown in the Sultanate of Oman. It occupies an average area of 6780 hectares. The average annual production is approximately 33680 tones with an estimated value of about US$20 million. In the Sultanate of Oman bananas are affected by diseases such as fruit rot (causal agent *Rhizopus* sp.), cigar end rot (causal agent *Verticillium theobromae*) and leaf spot (causal agent *Drechslera* sp.) The identification of resistance genes for these diseases is critical in order to create resistant varieties. Genetic transformation has proven to be a useful tool for creating plants with improved characteristics. Protocols have been developed for the improvement of Musa species through genetic engineering but most protocols are usually genotype–specific and therefore have to be tested in local Omani varieties. Thus this project has focused on developing suitable vectors for transformation of banana using two promoters, the cauliflower mosaic virus promoter (CaMV 35S) and the Sugarcane bacilliform virus Promoter (ScBV) and also to develop a method for the stable integration of transgenes into two local banana varieties, Malindi and Fardh. Suitable constructs have been prepared and currently tissue culture procedures are being optimized for the two banana varieties.

Ripening Profile of Semi Hard Standard Goat's Milk Cheese

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The microbial groups, physico-chemical characteristics, proteolysis, lipolysis and rheological properties over a 30-day ripening period of a semi-hard cheese from pasteurized goat's milk were investigated. The count of aerobic mesophilic flora was high in cheese throughout ripening, with lactic acid bacteria being the main microbial group. Halophilic bacteria, yeast and molds showed initial low counts but maintained their levels relatively constant during the ripening period. The main biochemical modification of cheese during ripening was related to the extent of proteolysis. The water soluble nitrogen in the semi-hard cheese increased during ripening. Lipolysis also occurred throughout the ripening period, with the major constituents being the palmitic, oleic, myristic, capric and lauric acids. The rheological study suggested that the most important factors influencing the texture of the goat cheese is the level of total solids and the extent of protein degradation recorded as soluble nitrogen during the ripening period. Rheological properties of goat cheese showed a transformation from a soft and elastic consistency to a hard and brittle body as a function of aging.

Keywords: Goat's cheese, microbial groups, proteolysis, lipolysis, texture.

Microbial and Physico-Chemical Characteristics of Dried Meat Processed by Different Methods

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Thirty longissimus dorsi (LD) muscles from Omani male goats were dried by five methods (sun, air, vacuum, freeze and modified atmosphere drying). Dried strips from the longissimus dorsi samples were evaluated for microbial, chemical and fatty acid composition and physical quality (pH, expressed juice, rehydration ratio, and color L*, a* and b* values). The method of drying had a significant effect on the microbial counts, pH, volume of expressed juice, color, rehydration ratio, and fatty acids content of LD samples. Immediately after drying and 6 weeks of storage, sun dried sample showed significantly higher aerobic plate counts, and levels of Pseudomonas and Staphylococcus compared to other methods of drying. The drying method significantly affected the types of mold growth in the samples.

Keywords: Freeze drying, modified atmosphere drying, sun drying, air drying, vacuum drying, meat quality.

Scleractinian Coral Biogeography and Taxonomy in Omani Seas

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Since Charles Darwin's first evaluation of the coral reefs of Oman our knowledge of the biogeography of coral communities in the Gulf of Oman has considerably improved. Because of its unique oceanography, the Sultanate is a keystone in the distribution of marine benthic species in the Indian Ocean. Already four species of corals have been described from Omani coral communities and appears to be either endemic or regional endemic (two within this study: *Calathiscus tantillus* Claerebout and Al-Amri and *Porites decasepta* Claereboudt. Off the approximately 140 species of reef building corals found in Oman, 50 have never been recorded previously and 12-15 species appears either endemic or regional endemic. The north (Musandam), center (Muscat) and south-east (Masirah-Dhofar) form three distinct regions in terms of coral communities.

Analytical Optimisation of Seepage Impeding Devices in the Vicinity of Oil Wells

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Recently developed Shell technology of de-anisotropisation of an oil formation in conditions of secondary oil recovery of a formation with fractures spanning from the aquifer towards the borehole is based on smart hydroisolation of certain well zones.

Steady, one-phase, 2-D, Darcian seepage is studied by the help of holomorphic functions and the method of analytic elements. Water flow occurs from a feeding contour and a fracture, which can be partially blocked, to a wellbore. Its surface is a composition of intermittently arrayed no-flow boundaries, which model the rubber seals, and isobaric lines, which model the compartments separated form the bulk of the borehole by these seals but commingled through essentially 2-D flow-through from one compartment to another. Pressure drops from the aquifer (fracture) to the compartments and further to the borehole that generates a hierarchy of flows mathematically equivalent to the Toth hydrogeological patterns of regional, intermediate and local groundwater flows on the scale of catchments. Conformal mappings of complex potential domains onto physical planes are used to tackle the fragments of the full feeding contour- fracture - sealed wellbore system. Explicit rigorous solutions for the flow characteristics (pressure and stream function) enable calculating optimal hydroisolation with a criterion of minimal flow rate from the fracture.

Cooling Greenhouses in the Arabian Peninsula

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Cooling greenhouses in the Arabian Peninsula is very crucial to extend the growing season. Since, the currently used greenhouses in this region are mostly imported from cold and wet countries the modification of greenhouses by including cooling systems, is a necessity. This poster presentation reviews modification and inclusion of cooling systems in the Arabian Peninsula The review is addressing the optimum application of the commonly used evaporative cooling systems.

In Kuwait, researchers conducted a study on four identical greenhouses but each installed with different cooling system; an upper positive cooling system, an upper negative cooling system, a lower positive cooling system, and a lower negative cooling system. In UAE, researchers added desiccant pads to the greenhouses for the purpose of removing the water vapor from the incoming air streams. They also used solar energy to regenerate desiccant solution to keep the desiccant properties. In Oman, researchers used sea water, instead of scarce freshwater for operating the cooling systems. They were able to reduce freshwater use of greenhouses from 2/3 to zero. In Bahrain, researchers came up with an oval-shape greenhouse enabling them to increase the cooling efficiency by reducing the air relative humidity before it passes over the cooling pads.

These studies gave positive results with respect to water consumption, profitability, and growing season extension. But they also concluded that additional research is required to determine an optimal configuration of a green house to meet climatic conditions of the Arabian Peninsula.

Significant Research Outcomes

Significant Research Outcomes

Composition Characterization and Thermal Transition of Date-Pits Powder
Shafiur Rahman, Stefan Kasapis, Nooria Al-Kharusi, Insaaf Al-Marhubi, and Akhtar Jamal Khan

Pits of date palm (seed) are a waste product of many date fruit processing plants producing pitted dates, date powders, date syrup, date juice, chocolate coated dates and date confectionery. At present, pits are used mainly for animal feeds in the cattle, sheep, camel and poultry industry. More value added caffeine-free date-pits-coffee could be developed when caffeine is a concern but a coffee-related flavor is desired. Thermal analysis was conducted for roasted, unroasted and defatted date pits powder using Differential Scanning Calorimetry (DSC) and Modulated Differential Scanning Calorimetry (MDSC). Endothermic events reflected ice and/or lipid melting dependent on the moisture content of the preparation. High solid materials are capable of holding up to 29.4% unfreezeable water in the matrix. Throughout the experimental temperature range (– 90 to 80^{o}C) there was no evidence of glass related processes, a result which could be attributed to extensive low-mobility or crystalline carbohydrate regions in the matrix. The proximate composition and other chemical compositions were also determined in relation to the thermal analysis.

Influence of Bruising and Storage Temperature on Vitamin C Content of Tomato Fruit
S.S. Sablani, L.U. Opara and K. Al-Balushi

Fresh fruit and vegetables are very important sources of vitamins that are essential for healthy human diet. The quality and nutritional status of fresh produce is affected by postharvest handling and storage conditions. This includes changes in vitamin content, loss of volatile aroma components and texture properties. Bruising is a common problem that downgrades the quality of fresh tomato during postharvest handling and marketing. Samples of bruised and undamaged tomato fruit were stored at two different temperatures for about two weeks. The temperatures selected were: refrigeration temperature (4^{o}C) and room temperature (25^{o}C). It was found that vitamin C content in fruit decreased with increasing duration of storage time at both temperatures, but no significant differences were found in vitamin C content of damaged and undamaged fruit tissue. The rate of vitamin C loss was higher when fruit were stored at higher temperature.

Freezing-Melting (FM) Process and Desalination: Review on Present Status and Future Prospect

M Shafiur Rahman, Mushtaque Ahmed and X. Dong Chen

A thorough literature survey was conducted on the freezing-melting (FM) process for desalination. Collected literatures were studied and analyzed to identify the current state-of-the-art of FM process and its practical limitations including present status and future prospect. The main factors affecting the use of FM process is the capital cost and complexity of the process. The technology was successful only when above mentioned two factors are compensated by other advantages, for example in case of food and chemical industries. The success in food industry was mainly due to its ability of producing high quality products compared to the available thermal technology in the market. In addition food is high value product compared to water. In case of chemical industry it is generally adopted when there are no other alternatives. It would be difficult to utilize the above advantages to progress the FM for desalination. In addition, misconceptions or negative attitude also affected the progress of FM process. In desalination, a numbers of existing technology are available. The practical difficulties of FM process limiting its commercial success are complexity of the process, and high capital costs. The pilot studies in several countries indicated that the hybrid techniques of combining FM process and other desalination methods have high potential for the future development. In this case solar assisted systems may have high potential. The strategies for the commercial success of the FM process in desalination industry are identified in this MEDRC funded project.

Moisture Sorption Isotherm and Anti-microbial Activity of Dried Garlic Powders Produced by Different Methods of Drying

Shafiur Rahman, Houd Al-Sheibani, Mohd Al-Riziqi, Ann Mothershaw, Nejib Guizani, Gunnar Bengtsson, Rashid Al-Belushi

Moisture sorption (adsorption and desorption) isotherm of freeze-dried garlic powder was measured by static and dynamic isopiestic methods. The isotherm was fitted with BET, GAB and Norrish models and critical evaluation on the physical meaning of the model parameters are presented. The dynamic method has the potential to be used in studying other structural and drying characteristics of foods. The anti-microbial activity of a range of garlic products including dried garlic powder produced by different methods, commercial garlic products, and garlic oil was determined at a range of selected bacteria. The bacteria included food borne pathogens,

spoilage agents, and health-beneficial agents, namely *Staphylococcus aureus*, *Escherichia coli*, *Salmonella typhimurium*, *Bacillus cereus*, and a mixed lactic culture consisting of *Lactobacillus delbrueckii* subsp. *Bulgaricus* and *Streptococcus thermophilus*. The dried powders were produced using air-drying at 60 and 80°C, vacuum-drying at 50 and 60°C, and freeze-drying at -20°C. Generally, fresh garlic produced the greatest inhibition followed by freeze-dried powder. The anti-microbial activity decreased with the decreasing dried garlic powder concentration. The results showed that both drying temperature and time have major effects on retaining the active components responsible for the inhibition of microbial growth.

Glycemic Index of Traditional Omani Breads

Amanat Ali, Hussain Al-Nassri, SS Iqbal, B. Al-Rasasi and B. Al-Belushi

Glycemic Index (GI) is a numeric physiologic classification of carbohydrate rich foods based on their glycemic responses during the postprandial period as compared to a standard food (either pure glucose or white bread). Foods with a low glycemic index have been shown to lower the risk of Type 2 diabetes and certain type of cancers, reduce the risk of coronary heart diseases (CHD), promote weight loss and help in control of obesity. The present study was conducted to evaluate the nutritional quality and glycemic index of some traditional Omani breads. Eight different types of commonly consumed Omani wheat breads were evaluated in this study. Significant ($P<0.05$) differences were observed in the proximate chemical composition, dietary fibre content and energy values of these breads. The moisture, crude protein, total fat, crude fibre, ash, and nitrogen free extract (NFE) contents (g per 100g on fresh basis) ranged 24.9-51.4, 3.7-10.3, 0.7-12.4, 0.2-1.1, 1.6-2.5, and 34.1-62.9, respectively. The energy content ranged between 216 and 428 kcal/100g of bread on as such basis. The glycemic index of these breads also differed significantly ($P<0.05$) and the values for White toast bread, Brown toast bread, Khubz Lebanani white, Khubz Lebanani brown, Chapati, Poratha, Goleh, and Rekhal were 62.8 ± 12.2, 57.8 ± 17.1, 62.5 ± 10.5, 56.6 ± 20.4, 58.2 ± 11.0, 31.8 ± 13.5, 42.9 ± 16.9, and 39.1 ± 8.3, respectively. White bread showed the highest whereas Poratha had the lowest GI values. The results of this study will help in developing the database on the proximate chemical composition and glycemic index values of the local Omani foods.

The Role of Education and Training Levels of Slaughterhouse Workers in the Cross Contamination of Carcasses
Ann S Mothershaw, Frisco Consolacion, Isam T. Kadim and Ahmed Noori Al Raisi

The annual incidence of illness related to food consumption remains high. Meat and meat products are commonly implicated vehicles for transmission of the causative agents. The hygienic status of the dressed carcasses leaving a slaughterhouse is largely dependent upon the skill with which the slaughterhouse workers remove the hide and internal organs and handle the carcasses. It also reflects the general hygiene standards of the workers and the slaughterhouse environment. The purpose of this study was to evaluate the knowledge of food safety issues, communication skills, and level of training amongst workers from a range of cultural backgrounds working in a slaughterhouse and to identify the relevance of these factors in the cross contamination of carcasses during dressing. Face-to-face interviews were conducted in a range of languages and the responses were recorded by the researcher on the questionnaire. The educational standards of the staff were generally low. Seventeen percent had no formal education and no common language was spoken by all workers. The most common languages spoken were Urdu and Hindi. Most of the workers (89%) had no training in safe food handling practices and more than half had received no training at the slaughterhouse. The personal hygiene standards of the workers were low and in general they did not view themselves or the equipment that they used as possible sources of contamination. The majority of the workers had a very limited understanding of effective cleaning regimes and sanitising procedures. The results emphasise the need for appropriate training programs to improve the knowledge of the workers and their practical skills to reduce the levels of contamination on carcasses leaving slaughterhouses.

Management of Salt-Affected Soils and Water for Sustainable Agriculture
(SR/AGR/SWAE/06/01)
Salim Ali Al-Rawahy et al.

After the meetings with investigators from SQU and the Agricultural Research Center (ARC) at Rumais a workshop was held at ARC on 18 November 2006 to finalize the research field plots details and responsibilities of investigators.

Installation of irrigation systems has been completed, soil samples from the fields taken for lab analyses and planting started on 22/3/07.

Four experimental plots have been planted with crops. Alfalfa grown under three irrigation systems- sprinkler, bubbler and subsurface drip- with three salinity levels and three irrigation levels, three phosphorus levels and three potassium levels all replicated three times in spli-plot design. Sorghum is grown in two experimental plots. One is under two salinity levels, three irrigation rates and three mulch treatments in split-block design while the other also drip irrigated but three salinity levels and four leaching rates with split-split-plot design. Similar experimental plot were grown with pearl millet with three salinity levels. All the treatments in the above plots were replicated three times. Whole plant samples were taken twice for salt distribution analysis and awaiting the third sampling during harvest. Whole plant pearl millet will be harvested on 18/6/07 while sorghum will have its first cut a week later thus giving chance for another cut 60-70 days later.

GIS information data of N and S Al-Batinah for 1991 Integrated Study collected from the MoAF have been used and maps have been produced showing soil salinity and other parameters. Sixty farms are being selected from these maps for visiting, taking soil and water samples for lab analyses and gathering necessary information for the project. The first visit was made on 10 May 2007 to Suwaiq. Based on the collected data, update soil salinity maps will be produced.

Results on integrating fish culture has shown that Nile tilapia fish gives better growth performance at 10 ppt salinity than in fresh water.

Water Quality Assessments in Jabal Akhdar (A subproject of the HM project 'Al Jabal Al Akhdar Initiative – Conservation and Sustainable Development in a Fragile Arid Mountain Ecosystem')
Reginald Victor (CESAR), Mushtaque Ahmed (SWAE) and M. Al-Haddabi (SWAE)

Rapid development in the Al Jabal Al Akhdar region of northern Oman is exerting pressure on water resources. Water quality and water use efficiency are the two most important management issues. Because of poor quality water in the reservoirs is under-utilized and groundwater faces the prospect of overexploitation. Management strategies are needed to tackle water quantity and quality issues in a sustainable manner. Water quality assessments and monitoring programs are valuable tools in formulating policies on proper water resources management. In this project (2004-2007) water quality assessments are being done through a comprehensive survey and in-depth look at two aquatic systems affected by environmental impacts relating to health, eutrophication and pollution. Based on the study,

monitoring strategies will be developed. Some sustainable management strategies will be recommended for implementation. It is expected that the research results will provide the foundation for the conservation of water resources and strategies for water use efficiency in the Jabal Akhdar region.
Based on the completed survey of about 50 surface water samples (reservoirs, *aflaj*, *weidan*), it can be said that surface water in Jabal Akhdar is not fit for drinking by humans. Samples were analyzed for temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Coliform and *Escherichia Coli*, Fluoride, Chloride, Sulphate, Nitrate, Sodium, Calcium, Magnesium, Potassium, and trace elements (Ni, Cu, Zn, Cd, Mn, Cr, Co, Fe, V, Ba). All samples clearly failed to satisfy Omani drinking water standards. The parameters which were not met include microbiological standards which are the most critical and decisive with regards to drinking water quality. Pesticides have been found in some systems and eutrophication is a common phenomenon in most reservoirs. Archival data have been compiled for more than 200 water bodies. Monthly monitoring of two locations has been completed for the period of one year. Comprehensive analysis of water quality data for survey samples and monitoring locations is in progress. Questionnaire survey to evaluate participation of local communities in water related issues is underway and installation of a pilot treatment unit at one village has been completed to study its impact on water use efficiency.

Postharvest Technology of Fresh Produce (SR/AGR/BIOR/05/01)
Linus Opara et al.

(1)Designed and developed a new device for measuring fresh produce susceptibility to impact damage. The novel feature of the new device enables is the automatic and objective measurement of the rebound angle (and hence equivalent drop height), which hitherto has been assessed subjectively by most postharvest researchers (paper published in the NZ J Crop & Hort Science, Vol. 35, 2007). (2) Developed an improved rapid procedure for spectrophotometric quantification of ascorbic acid (vitamin C) in collaboration with Dr Majeed Al-Ani (paper accepted in J. Food Agr & Environment). (3) Quantified the antioxidant components and mineral nutrient composition of locally grown banana (Salalah), which showed that the majority of locally grown banana had superior antioxidant and mineral nutrient properties in comparison with the commonly imported banana fruit. This first detailed postharvest analysis of locally grown banana cultivars has potentially major implications on dietary management of certain diseases

involving essential mineral nutrients such as potassium, which we found to be significantly higher in locally grown fruit.

Modeling of Groundwater in Two Selected Coastal Aquifers of UAE and Oman as a Precursor for Water Resources Management Collaborative Research Project (UAEU/SQU)
M. Sherif (UAEU), Anvar Kacimov (SQU)

The activities of the project included the following eight main tasks: 1- Data collection and selection of aquifers, 2- Drilling of observation wells (if needed), 3- Geophysical investigations, 4- Development, testing, calibration and validation of the analytical model, 5- Selection, calibration and validation of the numerical model, 6- Simulation runs and pumping scenarios, 7- Analysis of results and management plan, and 8- Reporting. Activities required for the completion of Tasks 6 and 7 are achieved using MODFLOW, a well-known groundwater software, for the coastal aquifer along the Kalbha and Fujairah coast of UAE. The model was developed and calibrated using hydrologic data obtained over the last 11 years. Results from this flow model were employed in the developed transport model to simulate salt-water intrusion into the coastal aquifer. Concentration contours for the salt-water in the aquifer were obtained. The results of both the analytical and numerical models indicated that seawater intrusion can be controlled either by pumping of brackish groundwater from the dispersion zone in the coastal area or by groundwater recharge. The location of pumping/recharge zones and the pumping/recharge rates depend on the hydrogeological parameters of the aquifers. Analytical and numerical models can be used to define the locations and rates of the required pumping/recharge activities to control seawater intrusion in coastal aquifers.

International Trade
Houcine Boughanmi, Slim Zekri and Juma Al-Musalami

Drs Boughanmi and Zekri, together with Senior Technician Musalami, have worked on international trade issues in the Gulf Cooperation Council (GCC) area. The overall objective of their project was to assess the trade potential of the GCC countries within the context of the old and emerging preference trade arrangements in the Middle East and North African (MENA) region. Results indicate that intra-GCC trade is higher than expected on the basis of underlying trade determinants. However, GCC intra-trade has not changed

significantly over the years and had probably reached its full potential during the first decade of the GCC creation. Trade with the Mashreq countries (Arabic speaking countries to the east of Egypt and north of the Arabian peninsular) are more than expected, while it is less than expected with the Maghreb countries (counties north of the Sahara and west of the Nile) despite the implementation of the GAFTA (Greater Arab Free Trade Area) a decade ago. The GCC trade with the European Union and the US was found to be quite intensive although no formal trade arrangement existed between the GCC and both blocs for the time-period used in the analysis. These results suggest that the newly signed trade arrangements are promising in enhancing new opportunities of trade in the GCC region.

Water Management
Slim Zekri, Hemesiri Kotagama, Houcine Boughanmi

Dr Zekri has led significant improvements in understanding of water markets in Oman. In a world of increasing water scarcity in some countries the development of applications of economics to production and allocation issues is of growing global importance. The consolidation of AERS as providing key expertise in the economics of water management has been demonstrated at two major international events: International Conference on Economic Incentives and Water Demand Management. SQU & MRMEWR, March 18-22, 2006. Muscat, and International Short Course on Economics of Water which was attended by 30 participants from 8 countries (Oman, Germany, Jordan, Bangladesh, India, Yemen, Tunisia, Syria). Sultan Qaboos University. 18-19 March, 2006.

Drs Zekri, Kotagama and Boughanmi published an economic analysis of selected characteristic markets for water in Oman in the Agricultural and Marine Sciences Research Journal, (Zekri, S.; Kotagama, H.; and Boughanmi, H.; 2006. Temporary Water Markets in Oman. 11 (SI), 77-84).

Summary of Internal Grant Projects Awarded in 2006

The Effect of Low Levels of Dietary Cobalt on Select Parameters of the Specific and Non-Specific Immune Responses of Omani Goats

E. Johnson, R. Al-Busaidy and K. Al Habsi

Department of Animal and Veterinary Sciences
College of Agricultural & Marine Sciences, SQU,
P.O. Box 34, Al-Khod 123, Sultanate of Oman

Duration: 3 years **Budget:** RO 10,200

Summary

Cobalt is synthesized by rumen bacteria to vitamin B_{12} which has two distinct but interdependent co-enzymatic functions. Sheep tend to be extremely susceptible to Co deficiency and develop anaemia, anorexia, reduced weight gains and photosensitivity Lacrimation, scaly ears, discoloration at the base of the wool, cardiovascular lesions and cerebrocortical necrosis have also been associated with low dietary levels of Co. In contrast to sheep, goats have been reported to be extremely resistant to low levels of dietary Co. However, in Oman, we have described in goats a commonly occurring condition referred to as hepatic lipidosis which we have recently experimentally reproduced by feeding a diet containing 0.1ppm Co/kg DM, an amount compatible with the minimum daily Co requirement of sheep We have also demonstrated that Omani goats fed low levels of Co exhibit a decrease in their apparent nutrient digestibility coefficients compared to goats supplemented with vitamin B_{12} and have poorer meat quality. Omani goats fed low levels of cobalt also exhibit a severe decrease in their serum vitamin B_{12} levels and clinically develop pale mucous membranes and have significantly lower weight gains. These animals show significant decreases in their red blood cell counts, packed cell volumes, mean corpuscular haemoglobin, mean corpuscular volume and mean corpuscular haemoglobin concentration, as well as in their total serum protein levels. No studies have been performed however to determine whether cobalt deficiency has an effect on the immune response of affected goats. Pilot studies in our lab however have shown that goats fed low levels of dietary cobalt have impaired non-specific immune responses characterized

by lower neutrophilic responses to opsonized zymosan than goats receiving parenteral injections of vitamin B_{12}. This affect appears to become apparent as early as four weeks after newly weaned goats are fed a diet containing low levels of Co. Accordingly, we have speculated that activities of the immune system may represent a more sensitive, functional indicator of suboptimal Co status than haematological indicators such as red blood cell counts and their indices that decline only after several months. The present study will attempt to elucidate whether cobalt deficiency has an effect on neutrophilic function, as well as cellular and humoral immune responses. Of particular significance is to determine whether Co deficiency alters the immunocompetency of goats potentially making them more susceptible to other diseases or alters their ability to respond to antigens such as vaccines. The totality of these results will grant a proper understanding of the pathodynamics of this economically important and production limiting disease of Omani goats.

Bioavailability of Iron in Various Types of Meats in the Sultanate of Oman

I. Kadim[1], M. Al-Ani[2], O.M. Gaafar[1], W. Al-Marzooqi[1] and E. Johnson[1]

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Duration: 3 years **Budget:** RO 10,000

Summary

Iron deficiency anemia is one of the most common diseases in the world including the Sultanate of Oman. It is associated with alternations in many metabolic processes in the body. The manifestations of these alterations have been noted in immune function, cognitive performance, energy metabolism and exercise or work performance. This study aims to investigate the bioavailability of iron, heme and non-heme iron in different types of meats. Rats will be used as a model for humans in relation to traditional eating habits in Oman. This aim will be achieved through three phases. The first phase aims to determine total iron, heme and non-heme iron concentration in various fresh and cooked meats. Fresh meat samples from goats, chicken, and fish will be collected. Meat samples will be cooked at 100°C and 140°C for 60 or 90 minutes for each. Total iron, heme and non-heme iron content will then be determined in fresh and cooked samples. The second phase aims to determine total iron, heme and non-heme iron digestibility coefficients of basal diets plus goat, chicken or fish meat using growing rats in a 3X3X3 factorial design experiment. Forty-eight male weaning rats will be randomly allocated to 12 test diets including goat, chicken, fish meats, with or without tea extraction, Arabian coffee extraction, or dates. The digestibility coefficient will be determined in rats of three different ages 60, 120 and 180 day-old. Effects of total iron, heme and non-heme iron bioavailability on performance and development of rats will be determined using radioiron isotopes in phase 3. Twelve experimental diets will be formulated to include the three types of meats with or without Arabian coffee extraction, tea extraction, or dates. Forty-eight rats will be randomly allocated to 12 test diets in individual cages with 4 replicates per treatment. Performance parameters of rats including

body weight, feed intake and feed efficiency will be weekly recorded between 30 and 180 days. At each age, blood samples, liver, carcass and non-carcass components samples will be collected to estimate the total iron, heme and non-heme iron concentration levels. The present study will lead to better understanding of the interaction between the most common eating habits including consumption of tea, coffee and dates along with meals.

Molecular Investigation of Lime Witches' Broom Phytoplasma in Oman

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Duration: 3 years **Budget:** RO 10,200

Summary

Lime (*Citrus aurantifolia*) has been a major commercial crop during 1970s. Traditionally, acid lime has become part of the daily diets of Omani people and others in the Arabian Peninsula. Sun dried and fresh acid limes are an essential part of the Arabian cuisine. In the early 1980s, Omani lime was found associated with witches' broom disease caused by wall-less microorganism called phytoplasma. By the end of 1990s, witches' broom disease has drastically reduced production of Omani lime by infecting more than 98% lime orchards throughout the Sultanate. Lime production in the Sultanate of Oman is urgently in need of being revitalized by developing sustainable integrated disease management using molecular and conventional techniques. Molecular survey of lime orchards will provide information whether one or more phytoplasmas are involved in disease development and if there are any resistant or tolerant lime trees available. Removal of weeds or other wild plants carrying phytoplasma DNA detected by molecular survey would allow in reducing the source of spread of phytoplasma. Putative insect vectors will be surveyed from infected orchards and transmission tests will be carried out on lime seedlings and/or periwinkle using dodder. All molecular tests will be standardized to identify lime witches' broom phytoplasma(s) from different parts of the plant. Gene for resistance or tolerance to lime witches' broom phytoplasma in asymptomatic lime plants will be identified by RAPD, subtractive hybridization and other molecular techniques. The research proposal will provide molecular data on lime witches broom disease, alternate host and insect vectors, possible search of gene for resistance to lime witches broom phytoplasma(s).

Collection and Evaluation of Native and Exotic Germplasm of Important Crops of Oman

A. Al-Maskri, I.A. Khan and M.L. Deadman

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Duration: 3 years **Budget:** RO 8,000

Summary

Little is known about the diversity of cultivated crops in Oman and their morphological variation, and their agronomical properties such as tolerant against drought and salinity. Agriculture in Oman has been undergoing modernization which includes the introduction of seeds of exotic varities. The continuing exotic introductions have enabled large scle of production of modern varieties. However, the uncontrolled introductions have brought unforseen diseases and insects and have led to a withdrawal of farmer's attention from traditional crop varieties. The traditional crop germplasm sustained agriculture in Oman for centuries and now faces extinction. These races hold exceptional adaptive advantage which should be preserved and propagated. This project aims at extending the collection of land races and exotic varieties of important crops. A project was initiated during 1999 for collection of germplasm and seed production. The ongoing project ended by 31st December 2003. We have developed some protocols to provide a basis for indigenous seed production of well adapted local and exotic land races and cultivars. Eight international research papers were published, several conference presentations have been made. Postgraduate students are involved in this research (MSc and PhD), one PhD student graduated August 2004, and technicians have been trained. Overseas collaborations have been established. This proposal seeks funds to renew the ongoing effort with some essential modifications in the objectives and methodology.

A scientific basis shall be provided to initiate a seed registration and certification program in Oman.

Mango Rootstock Evaluation, Conservation and Use in Sultanate of Oman

M.L. Deadman, R. Al-Yahyai and Y. Al-Maqbali

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SQU, P.O. Box 34, Al-Khod 123, Sultanate of Oman

Duration: 3 years **Budget:** RO 7,100

Summary

The proposal aims at the development of genetic material resistant to the mango decline pathogen *Ceratocystis fimbriata.* Pathogenicity studies and molecular characterization of the pathogen will allow comparison of local mango rootstocks cultivars with known polyembroyonic mango rootstocks, collected from different areas in the world, for their ability to resist *Ceratocystis fimbriata*. Omani mango germplasm found in the field to be tolerant (or resistant) to mango sudden decline disease will be evaluated.

Screening of Lettuce Cultivars for Production Under Different Shade Levels

F.A. Al-Said, I.A. Khan and M.L. Deadman

Dept of Crop Sciences, College of Agricultural & Marine Sciences,
SQU, P.O. Box 34, Al-Khod 123, Sultanate of Oman

Duration: 3 years **Budget:** RO 4,720

Summary

Lettuce *Lactuca sativa* is one of the major salad crops grown in large areas in different parts of the world. In Oman the consumption of lettuce increased over the recent years; where most of the quantities consumed are imported. This is a proposal to investigate environmental factors to grow different lettuce types under shade levels combined with ambient temperatures trying to establish a common growing practices and seasons for lettuce production in the Sultanate; and screening the different types and varieties in an attempt to introduce the crop to the framers in order to increase their income.

Cultivation of vegetables under shaded area is becoming a common practice in the modern farms in Oman to produce specialty crops or out of season production. However, this is not realized by the common farmers where the direct benefit is not recognized for extra cost to the production. In recent years cucumber became a high cash crop and resulted in a shift in vegetable production map in the Sultanate. Use of greenhouses kept production all year around even in the summer under high temperatures that reaches 48 ^{o}C in some areas due to use of different materials to shade the green houses.

This project aims at quantifying effect of different shade levels on lettuce production during different times of the year to identify proper growing seasons through introduction of new varieties of lettuce. By the end of the project, it is anticipated to find new varieties of lettuce that are suitable for cultivation in Oman and thus introducing the crop to farmers. The successful cultivars of lettuce will reduce import requirements, while enhancing the income of the farmers.

Physiological Responses of Date Palm to Various Levels of Water Stress

R. Al-Yahyai[1], M.O. El-Mardi[1], F.A. Al-Said[1], H. AbdelRahman[2], L. Al-Kharusi[1] and Harith Al-Nabhani[3]

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Duration: 3 years **Budget:** RO 4,480

Summary

Physiological responses of fruit crops can be used as indicators of water stress due to low soil water content and can be used to assess tree water requirements. Leaf gas exchange and tree stem and leaf water potentials are the most commonly used stress indicators and have been found to be correlated with growth and yield of several temperate, subtropical, and tropical fruit crops. However, little is known about the physiology of date palm under environmental stress conditions. The objective of this study is to investigate the physiological responses of date palm to water stress. Leaf water potential and photosynthetic activity of date palm will be determined and correlated with various levels of soil water contents. The expected results will provide information on the response of date palm to water stress under northern Oman climatic conditions that can be used to assess tree water requirements and to compare the validity of soil water content measurements and tree water status indicators.

Comparative Studies of Size-Fractionated Phytoplankton Primary Productivity and Bacterial Biomass and Production in Bandar Khayran Bay, Gulf of Oman and Masirah Island, Arabian Sea

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Duration: 3 years **Budget:** RO 11,500

Summary

The recent observations of decreasing winter and spring snow cover over Eurasia is resulting in a land-ocean thermal gradient which seems particularly favorable to stronger southwest (summer) monsoon generation. Since 1997, sea-surface winds have strengthened in the western Arabian Sea resulting in an enhanced upwelling along the coasts of Somalia and Oman and almost a fourfold increase in Chla biomass, which raises the possibility that Arabian Sea under this influence could become more productive. Recent observations of small and large pelagic fish landing data seem to be consistent with this data and indicate that while total (on a weight basis) small and large pelagic fish landings north of the Ras Al-Hadd area (Gulf of Oman) are decreasing, these values in the south of this region (Arabian Sea) are increasing. We have therefore, proposed to conduct an oceanographic comparative study of Bandar Khayran Bay (Gulf of Oman) and the waters off Masirah Island (Arabian Sea) to examine the nutrients, biomass and phytoplankton primary productivity as well as bacterial abundance and production rates to determine if these two bodies of waters show distinct physical, chemical and biological differences in order to illuminate the biogeochemical basis of any differences that may promote enhanced understanding of ecosystem structure and function in the Arabian Sea.

Effect of Manure Amendment with Varying C:N Ratios on N Mineralization in Soil

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SQU, P.O. Box 34, Al-Khod 123,
Sultanate of Oman

Duration: 3 years **Budget:** RO 4,400

Summary

Application of organic manures into the Al-Batinah region soils is a common practice for higher agricultural production (Al Gaithi, personal communication). However, little, if any, work has been done on the effects of manure type and quality on N dynamics, specifically mineralization, in these soils. Such knowledge may be used for improving and quantifying nitrogen use efficiency. Objectives of this study will be (i) to investigate the effect of C:N ratio of manure on nitrogen mineralization, (ii) to monitor N availability with time in soils amended with different organic amendments, (iii) to examine the ideal C:N ratio in terms of N availability and yield under the conditions of our experiment, and (iv) recommend appropriate way of managing these different types of organic fertilizer for higher yield and profit. In order to accomplish these objectives, a pot experiment will be conducted. Agricultural soils from AL-Batinah region will be collected, mixed, and amended with different types of organic manures that include cow, goat, chicken, and some commercial ones. Rhodes grass will be grown in these pots. Nitrogen and selected physio-chemical parameters and yield will be monitored and measured along the course of this study.

Design and Construction of Greenhouses for Arid Regions

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College of Agricultural & Marine Sciences,
SQU, P.O. Box 34, Al-Khod 123,
Sultanate of Oman

Duration: 3 years **Budget:** RO 4,400

Summary

Modifications on the design of greenhouses used currently in Oman will take place in this project and these modifications will be used to construct new greenhouses. The new design will take into account the environmental and climatic conditions of arid regions and especially Oman for the purpose of improving the performance of the greenhouses to produce a better quality and high yields of different crops grown in these greenhouses.

Summary of Strategic Research Project Awarded in 2006

Management of Salt-Affected Soils and Water for Sustainable Agriculture

Al-Rawahy, S.[1], N. Hussein[2], M. Ahmed[1], A. Al-Bakri[2], M. Al-Wardy[1], S. Al-Habsi[2], H. Esechie[1], S.A. Shahid[3], O.M. Gaafar[1], S. Goddard[1], S. Al-Khanbasi[4], S.K. Nadaf[2], S. Zekri[1], A. Al-Barhi[5], S.S. Al-Ismaily[1], A.M. Mahruki[1], A.S. Al-Harthy[2], M.A. Mirza[6] and M.K. Al-Rashdi[2]

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[3] International Center for Biosaline Agriculture (ICBA), Sultanate of Oman
[4]Ministry of Regional Municipality & Environmental Water Research, Sultanate of Oman
[5]Agricultural Development, North Batinah, Ministry of Agriculture and Fisheries, Sultanate of Oman
[6]LRC, Ministry of Agriculture and Fisheries, Sultanate of Oman

Duration: 3 years **Budget:** RO 95,000

Summary

Soil salinity is a serious threat to Omani agriculture and its economy. It also leads to desertification of landscapes. Most of the Al-Batinah soils are coarse textured and therefore have unimpeded drainage that reduces buildup of salts if properly managed. Appropriate solutions which are environmentally sustainable need to be identified and promoted. Furthermore, there is a need to utilize land and water resources in the country, which are of marginal quality. The project will focus on three approaches- soil reclamation, biosaline agriculture and integrating fish culture into crop production which could have a compensatory economic return to the farmer. Research should also focus on developing a rapid and inexpensive method to monitor land salinization, and the impact of interventions to mitigate salinization. In addition, the socio economic benefits and cost of salinization need to be well understood before government funds are invested to mitigate salinization.

The College of Agricultural and Marine Sciences (CAMS) at Sultan Qaboos University (SQU) and Agricultural Production Research Center (PPRC) of the Ministry of Agriculture and Fisheries (MAF) have conducted some laboratory and field salinity research. However, the studies have not been extended to farmer's fields- a deficiency that will be systematically addressed in this study.

In this project 5 departments from CAMS at SQU will work together with the PPRC of MAF, Ministry of Regional Municipalities, Environment and Water Resources (MRMEWR) and International Center for Biosaline Agriculture (ICBA) to develop applied scientific management guidelines/practices to salt-affected soils for sustaining agricultural production, thus contributing to combating desertification.

The project will also employ two Omani graduate students as research assistants to enhance their capabilities to conducting research of meeting the challenges of agricultural land salinization. It will also explore the possibility of establishing a Salinity Research Center.

Specific objectives of the project are to:

1. Assess the intensity and extent of salinity in the Al-Batinah Region using remotely sensed satellite images and ground truthing and preparation of temporal and spatial variation maps of salinity of soil and water from GIS.
2. Determine agronomic solutions (mulching, tillage, sowing methods, etc.) and nutritional aspects including microbial nitrogen mineralization in saline conditions.
3. Determine engineering and water management solutions (irrigation, sub irrigation, leaching, leveling etc.) to reduce of water loss and salinisation.
4. Determine biological solutions by identifying salt tolerant crops, and fruit trees for various salt-affected regions of Oman. This includes introduction of halophytes.
5. Assess the effects of feeding salt-tolerant forage crops to Omani sheep.
6. Integrate fish culture in marginal lands.
7. Determine socio economic costs and benefits of salinity management practices in the Al Batinah region.

Graduate Program

Graduate Program

The Masters program, now in its tenth year continues to attract hardworking and enthusiastic students.

The program offers curricula in Agricultural Economics, Animal and Veterinary Sciences, Crop Production, Crop Protection, Food Science and Nutrition, Marine Science and Fisheries, Soil and Water Management and Agricultural Engineering.

Fifteen were enrolled for the academic year 2006 bringing the total number of graduate students to 95. Nineteen students graduated in the year 2006 (including 3 who were awarded graduate diploma).

Graduate students are involved in funded research projects as part of the masters' requirements. This strengthens the quality of their projects and provides them with the tools necessary to conduct practical research in their work areas.

Various abstracts of the thesis work done by the graduate students are presented in pages 66 to 91.

A proposal to embark on a PhD program with more comprehensive requirements for research has been approved by the University Council.

Thesis Abstracts of Students Graduated in 2006

Title	:	Adoption of E-Commerce in Agribusiness in Oman: Perception and Barriers
Student Name	:	Zahra Yakoob Al-Busaidi
Supervisor	:	Dr. Hemesiri Kotagama
Department	:	Agricultural Economics & Rural Studies

Abstract

The objective of this study is to assess the factors causing the adoption of e-commerce in the agribusiness sector in Oman. Previous research suggests that adoption of e-commerce depends on internal factors that relate to individual businesses and external factors relating to government policy, legal aspects and supporting public infrastructure. Among the internal factors that relate to the adoption of e-commerce, benefits of e-commerce in improving functions of the supply chain as perceived by business managers are considered as critical factors. Hence the main hypothesis of the study is that perceived benefits by managers from adopting e-commerce in improving functions of the supply chain influences the adoption of e-commerce.

The data was obtained from a random sample (n = 31) of agribusiness in Oman using a structured questionnaire and through mail survey. The questionnaire sought information on type of business, product and employees' education etc, general opinion of business managers about the adoption of e-commerce, barriers affecting the adoption of e-commerce, factors supporting the adoption of e-commerce. The data was analyzed by using descriptive statistical methods and a Probit regression model. The dependent variable of the regression was whether the firm has a website. The independent variables consist of a number of variables that related to perception of benefits of adopting e-commerce in improving function of the supply chain and two other factors namely the size of the business and the scope of the business (international or national). Perceptions on benefits of e-commerce by business managers were measured on a Likert scale.

It was found that although businesses use computers (94% of businesses) and about 52% of the businesses have websites, only a small percentage (3.2%) engaged in all aspects of e-commerce. The R-squared, of the estimated Probit regression model was 0.65. All the signs except of the "Security" variable (e-commerce reduces security of business transactions) had the

hypothesized signs. Of the variables confirming with hypothesized sign, the "Size" of the Company (measured by number of employees) was significant at 5% level of significance. The other variables measuring perceptions on benefits on adopting e-commerce by managers were not significant.

The study found that perception of managers on benefits of e-commerce did not influence the adoption of e-commerce. The only variable that explains the adoption of e-commerce is the size of the business.

Title	:	Effects of Season, Housing Type and Ascorbic Acid Supplementation on Performance, Carcass and Meat Quality Characteristics of Broiler Chickens in the Sultanate of Oman
Student Name	:	Bader Ali Hamed Al Qamshoui
Supervisor	:	Dr. Isam Kadim
Department	:	Animal & Veterinary Sciences

Abstract

A study was conducted to investigate the effects of season, housing type and ascorbic acid supplementation on performance, carcass and meat quality characteristics of commercial broiler chickens under Omani conditions. Two houses (closed and open-sided houses) and four levels of ascorbic acid (000, 100, 200 and 300-ppm) were used in the cool and hot season experiments whereas one house (open-sided house) and four levels of ascorbic acid (000, 100, 200 and 300-ppm) were used in the mild season experiment. Four-hundred and thirty two day-old Cobb-500 broiler chickens were randomly and equally divided into open-sided house and closed house. Within each house, birds were randomly allocated into four treatments with six replicates each containing nine birds. In the mild season experiment, 216 birds were randomly allocated into four treatments with six replicates each containing nine birds. Daily minimum and maximum temperatures for outside and inside houses and relative humidity readings were recorded. Weekly rectal temperatures, mortality rate, feed intake, weight gain and feed conversion ratio in broiler chickens were measured. At the end of the experimental period (42 days), two birds from each pen were randomly selected and slaughtered to evaluate the effect of housing type and ascorbic acid supplementation on carcass and meat quality characteristics.

There were large differences in the range of ambient temperatures between hot, cool and mild season experiments; (32-45°C), (22-28°C) and (25-35°C), respectively. Temperature inside the closed house was not affected by these seasonal changes because of the efficient cooling system. On the other hand, the open-sided house was much affected by the ambient temperature and relative humidity outside the house especially during hot season. This

resulted in appearance of heat stress classical signs in birds such as panting and wing lifting during the hot season.

Rectal temperatures in control birds in the open-sided house during hot season (40.3-42.5°C) were significantly ($p<0.05$) higher than those in cool season (40.1-41.5°C) and mild season (40.7-41.4°C). Control birds significantly ($p<0.05$) consumed 12.8 and 12.2% less feed in the hot season than their counterparts in the cool and the mild seasons, respectively. Similarly, body weight gain was 15.7 and 17.0% less in the hot season than in the cool and the mild season, respectively. Ascorbic acid supplementation improved broiler performance, carcass and meat quality characteristics with the effect been more pronounced in the hot season. Feed intake was improved by 6.6, 28.7 and 3.6% with 300-ppm ascorbic acid supplementation in the cool, hot and mild seasons, respectively. Body weight gain was also improved by 7.0, 29.0 and 7.3% with 300-ppm ascorbic acid supplementation added in the cool, hot and mild seasons, respectively. On the other hand, mortality rate was reduced; carcass and meat quality characteristics were improved by supplementing ascorbic acid during hot season. This study indicated that supplementing ascorbic acid will be beneficial to small-scale farmers in the open-sided house type under Omani conditions during the hot season of the year.

Title	:	Efficacy of Different Control Measures for the Management of Muskmelon Late Vine Decline in Oman
Student Name	:	Mahmoud Mohammed Al Nabhani
Supervisor	:	Dr. Michael Deadman
Department	:	Crop Sciences

Abstract

Muskmelon late season vine decline (MLVD) has become more predominant in muskmelon cultivation in Oman. A survey conducted in the Al Batinah region showed that more than one soilborne pathogen is associated with MLVD disease. *Pythium aphanidermatum, Fusarium* spp., *Rhizoctonia* sp. in addition to nematodes were isolated from infected roots, crowns and stem tissues. Disease symptoms were similar in all fields included in the survey. Wilting of the plant canopy about two weeks before harvest was common. Brown to Dark brown lesions were scattered over primary, secondary and tap roots. Sloughing-off of cortical tissues of the root system in advanced disease stages was associated mainly with *P. aphanidermatum. Fusarium* species were involved in strangled crown areas and with discolored vascular tissue of roots, crowns and stems. In most cases, a short tap root was a distinctive symptom.

Two field experiments were conducted in different locations with different soil characteristics to evaluate different control measures in their efficacy in reducing the density of inoculum and AUDPC and consequently increasing yield. At Al Sawadi, metalaxyl was added at the rate of 100ml/plant via a separate drip irrigation system throughout the growing season. Metam sodium was applied as preplant treatment in aqueous form at the rate of 226ml/2m^2 via a drench method. Cabbage residue was burried as a preplant treatment at the rate of 20 kg/2m^2. At Wadi Al Abiath, cabbage residue was added at the same rate as in the first trial. Metam sodium was applied using the same method but at an increased rate (250ml/2m^2). A fungicide mixture (Tachigaren, Hymexazole, Tolclfos S-methyl and Thiram, Topsin, Thiophonate methyl was applied via a drench method around the root zone. Oxamyl 10% was added as granules prior to and after sowing.

In both trials, metam sodium showed the best results in reducing inoculum levels. At Wadi Al Abiath, metam sodium significantlly reduced AUDPC. In both trials, none of the treatments showed a significant impact in increasing fruit yield. Moreover, both varieties examined were susceptible to MLVD disease. Out of thirty two exotic varieties evaluated, Panna, Canal261 and Kurooger showed tolerance to MLVD.

Title	:	Molecular Characterization of Phytoplasma Causing Alfalfa Witches' Broom Disease in Oman
Student Name	:	Ali Masoud Saeed Al-Subhi
Supervisor	:	Dr. Akhtar Jamal Khan
Department	:	Crop Sciences

Abstract

Witches' broom of alfalfa (*Medicago sativa* L.) is a serious disease caused by a phytoplasma in the Al-Batinah, Al-Sharqiya, Al-Dhahera, and interior regions of the Sultanate of Oman. Disease incidence was recorded to be 95% in 6 year-old alfalfa crop during field survey. Phytoplasma bodies were detected by 4,6-diamidino-2-phenylindole (DAPI) staining in alfalfa plants showing witches' broom symptoms. Results obtained from transmission electron microscopy revealed the presence of numerous phytoplasma cells in phloem sieve-tube members in diseased plants but not in healthy tissues. Total nucleic acid isolated from symptomatic alfalfa was used as template to amplify 16S-23S ribosomal DNA and spacer region by polymerase chain reaction (PCR) using two pairs of universal primers as direct (P1/P7) and nested (R16F2n/ R16R2). The PCR amplifications yielded 1.8 and 1.2 kb fragment from direct and nested PCR respectively from DNA of symptomatic alfalfa. Restriction fragment length polymorphism (RFLP) profiles of direct PCR products amplified from symptomatic alfalfa and 19 phytoplasmas from different groups used as positive control with *Tsp509*I, *Rsa*I, *Taq*I, *Tru9*I, and *Hpa*II restriction enzymes clearly indicated that alfalfa phytoplasma is different from all other phytoplasmas employed in this study belonging to subgroup 16SrII, except tomato big bud (TBB) phytoplasma from Australia, and could be therefore classified in TBB subgroup, 16SrII-D. The P1/P7 PCR product was sequenced after cloning and yielded 1690 bp product. The alfalfa witches' broom (AlfWB) phytoplasmsa showed >98% similarity with papaya yellow crinkle (PapayaYC) phytoplasma from New Zealand in the homology search and <98% similarity with LWB phytoplasma. These finding were supported by phylogenetic analysis that showed AlfWB clustering with FBP group (16SrII) and PapayaYC belonging to the same group. On the basis of results obtained from restriction fragment length polymorphism and nucleotide sequence analyses of 16S rDNA, the AlfWB phytoplasma was classified in FBP group (16SrII), designated subgroup II-D.

Title	:	Use of Date Palm Leaf Base-Derived Compost as an alternative to Peat Moss in the Production of Flowering Bedding Plants
Student Name	:	Badr Ali Mohammed Al-Bahri
Supervisor	:	Dr. Mahdi O. El-Mardi
Department	:	Crop Sciences

Abstract

Peat from date palm (*Phoenix dactylifera*) leaf bases was produced by a fermentaion process. Physical and chemical properties, such as pH, electrical conductivity (EC), macronutrient availability, total phenol and water holding capacity (WHC) of commercial peat moss (CP) and produced peats; fermented date palm leaf base peat (FLBP), dry date palm leaf bases peat (DLBP) and leached date palm leaf base peat (LLBP) were determined. The results showed no significant differences in most of the physical and chemical properties of peat mixes. All media mixes had pH and EC higher than CP, whereas, DLBP produced the higher total phenols than the other mixes, FLBP caused insignificant increase in WHC over CP and FLBP with CP, but significantly different from the remaining media. Produced peats from date palm leaf bases and CP were tested for their effects on the growth of some bedding flower plants: Zinna (*Zinnia elegans*) and Marigold (*Tagetes erecta*). There were no significant differences in plant height, number of leaves per plant, number of leaves per cm, number of flowers, growth rate and dry matter of shoot and root of Zinnia and Marigold plants in the potting media containing the CP and FLBP. In many casses, FLBP shown better results than CP. Also, date palm leaf base peat cost is lower than the commercial peat moss by 63 %. Producing date palm leaf base peat has a friendly environment impact: it contributes to the disposal of large quantities of plant waste and reduces air pollution caused by burning palm leaves.

Title	:	Genotypic and Explant Effects on iIn vitro Callogenesis and Regeneration of Eight Accessions of Tomato
Student Name	:	Tina Susan George
Supervisor	:	Dr. Iqrar A. Khan
Department	:	Crop Sciences

Abstract

Eight accessions of tomato were tested for *in vitro* regeneration responses. Two explants i.e. fully expanded true leaves and cotyledon leaf were cut into leaf discs and cultured on two distinct media. Murashige and Skoog salts were modified with 6-Benzylaminopurine (1.0 mg/l) and 1-Naphthaleneacetic acid (0.1 mg/l) and 3-Indoleacetic acid (0.1 mg/l) and zeatin (1.0 mg/l) for true leaf and cotyledon leaf explants, respectively for callus induction. For shoot regeneration, Murashige and Skoog salts modified with zeatin (2 mg/l) and 3-Indoleacetic acid (0.1 mg/l) were used for each of two explants. Data were collected for the percentage of callus induction, callus fresh weight, callus size and number of shoots. There were significant genotypic and explants effects observed for initiation and growth of callus. The highest percentage (47) for callus induction was for accession PT4719A. Shoot regeneration occurred after repeated subcultures. Again, genopytic and explant effects were significant. All accessions regenerated plantlets from true leaf explants whereas cotyledon leaf explants of accessions PT4719A, PT4664B and CLN2116B were unresponsive for callus induction and regeneration. The highest percentage of callus was 100% in the case of cotyledon explant of accession CL5915-206. The highest area of callus spread for true and cotyledon explant was observed in PT4719A (2.68 cm^2) and CLN2123A (2.59 cm^2) respectively. Amongst true leaf and cotyledon leaf explants, the callus fresh weight was highest for CLN2123A (1.52 mg) and CLN2026D (2.53 mg), respectively. CLN2026D also produced highest number of shoots per callus (12) from cotyledon explant and 0.4 from true leaf explant. PT4719A gave highest number of shoots per callus from true leaf explant (4.6) whereas it was unresponsive for cotyledon leaf regeneration. The results showed that though some accessions like PT4719A gave highest regeneration response for true leaf explants, it was totally unresponsive for cotyledon explants. In the case of cotyledon explants, it was observed that there was no correlation between the percentage of callus induction and

number of shoots per callus. There was no direct correlation between percentage of callus induction, callus weight, size and number of shoots regenerated for any of the genotype and explant combinations. Clearly, the genotype and explant effects were significant.

Title	:	Instrumental-Sensory Texture Evaluation and Storage Stability of Geelbebeck Croaker Sausage
Student Name	:	Humaid Ali Abdullah Alwaili
Supervisor	:	Dr. Shafiur Rahman
Department	:	Food Science & Nutrition

Abstract

Many fish products, such as fish burger, fish nuggets, fish fingers, fish kabab, fish sausage, and surimi could be developed with tailoring the preferences of the targeted consumers. Fish sausage could be one important product for the local and international market due to its recent demand for its beneficial effects in human health, low cost due to the use of low-grade fish species (by catch), and possibility of value addition to the fish. First the effect of starch in 8 formulations was studied by changing its level from 0-48% based on raw fish. Four sensory and four instrumental textural attributes (hardness, brittleness, adhesiveness, and firmness), and desirability (i.e. preference) of overall texture were considered in assessing the sausages. The instrumental adhesiveness and firmness were found insignificant ($P>0.05$), while all other attributes for sensory and instrumental showed significant ($P<0.05$) change with the formulation (increasing starch). All sensory attributes showed high correlation with increasing starch. However, only instrumental hardness among the other instrumental attributes showed high correlation with increasing starch level. Both instrumental and sensory hardness increased with the increase of starch content whereas brittleness decreased with the increase of starch content. Instrumental hardness was highly correlated with sensory hardness ($r^2=0.66$), followed by adhesiveness ($r^2=-0.15$), firmness ($r^2=0.12$), and brittleness ($r^2=0.06$). This indicated that only sensory hardness could be reasonably measured by instrumental method. The formulation containing 8% starch gave best overall textural desirability. This was due to the structure forming ability of starch. In second series of experiments 6 formulations were considered considering 8% starch content with varying spices levels. The addition of spices resulted significant improvement in overall consumer acceptance ($P<0.05$). The optimum formulated sausage with additional spices produced in the laboratory showed higher acceptance compared to the commercial one. The color *L*, *a*, and *b* values of formulated

and commercial sausages showed significant change during frozen storage. The change of aerobic plate count was significant for formulated sausage in the laboratory ($P>0.05$), whereas for commercial sausage the change was insignificant ($P<0.05$). The average of coliforms in formulated sausage during storage decreased from 2.2 to 0.8 MPN/g, whereas in case of the commercial sausage most probable number decreased from 52.67 to 10.2 MPN/g.

Title	:	Physico-Chemical Properties of Roasted Date Pits
Student Name	:	Nooria Al-Kharusi
Supervisor	:	Dr. M. Shafiur Rahman
Department	:	Food Science & Nutrition

Abstract

Value added products, such as roasted date-pits powder, and date-pits oil, could be developed from date-pits byproducts from whole dates. In order to develop quality products, it is important to understand the structural characteristics of date-pits. In this project, the chemical composition and thermal characteristics of un-roasted and roasted date-pits were measured. The moisture content of roasted pits powder was 1.63% (wet basis) and soluble solid in water-extract was 6.57%. Protein, fat, ash, carbohydrate, and crude fiber were found 6.96, 7.95, 0.96, 61.50, and 21.00%, respectively. Carbohydrate is the main solid component of date-pits. The amount of total sugars was 2.93%, while reducing and non-reducing sugars were 1.09% and 1.84%, respectively. Fatty acid analysis indicated that lauric acid (C12) and oleic acid (C18:1) were the major fatty acids in roasted date seeds, followed by palmitic acid (C16) and linoleic acid (C18:2). With regards to mineral content, potassium (K) was the highest followed by phosphorus (P), magnesium (Mg), calcium (Ca), sodium (Na), and iron (Fe). Other minerals were less than 10 mg/kg sample, while lead (Pb), cadmium (Cd), and chromium (Cr) were at trace levels. The melting point (peak of the endotherm) and latent heat of melting of pure date-pits oil were found to be 1.8^{o}C and 68.1 J/g, respectively. Thermal analysis was conducted for roasted, un-roasted and defatted date-pits powder using Differential Scanning Calorimetry (DSC) and Modulated Differential Scanning Calorimetry (MDSC). The heating thermogram showed an endothermic peak (for ice and/or fat melting) and no evidence of glass related processes within the temperature range of –90 to 80^{o}C. The endothermic peak for the lower moisture sample was mainly due to the melting of relatively bound lipids in the matrix since all water in the sample was un-freezable. The missing of a glass transition could be explained by the fact that the date pits contained a high ratio of low-mobility ordered regions to amorphous domains. This would enhance strong interactions and a percolation effect (clustering)

between adjacent sequences, thus rendering free-volume effects insignificant within the accessible temperature range. The roasted sample with fat showed higher un-freezable water of 29.4%, while the other samples showed lower values; 22.2 - 23.9%.

Title	:	Effects of King Fish Oil on the Atherogenic Lipid Profile of Experimentally-Induced Hypercholesterolemic Rats
Student Name	:	Bashair Abdullah Al-Riyami
Supervisor	:	Dr. Ishtiaq Mahmud
Department	:	Food Science and Nutrition

Abstract

Over the last 25 years, the cardiovascular effects of marine omega (□)-3 fatty acids (also referred to as n-3 fatty acids) have been the subject of increasing investigations. In the late 1970's epidemiological studies revealed that the Greenland Inuits had markedly reduced rates of acute myocardial infarction compared with Western controls. These observations spawned hundreds of subsequent studies, beginning with the initial epidemiological observations and then moving to cell culture, animal and clinical studies, all of which confirm the cardioprotective effects of n-3 fatty acids.

This investigation was therefore, initiated in order to clarify the effects of king fish oil on the concentration of lipids, nonesterified fatty acid and total antioxidant status in the serum of experimentally-induced hypercholesterolemic rats. Wister rats were randomly divided into five groups: control group (Group A), group B, C and D were fed high cholesterol (HC) diet (2%) for 4 weeks followed by another 4 weeks of HC diet, normal diet and fish oil (FO) (5%) diet, respectively. In group E the rats were co-fed with HC plus FO diet for 8 weeks. As expected serum total cholesterol in rat increased significantly ($P< 0.05$) following feeding of high cholesterol diet (118±2 mg/dl) in comparison with group A (59.2±7.6 mg/dl). This increase was due to raised very low density lipoprotein (VLDL-) and low density lipoprotein (LDL-) cholesterol. Dietary fish oil significantly decreased the serum total cholesterol by 63%, triglycerides by 43% and nonesterified fatty acids by 65% with concomitant increases of total antioxidant status (95%) and high density lipoprotein (HDL-) cholesterol (26%).

In group E, FO diet seems to prevent any increase in serum total cholesterol and NEFA levels compared to Group B level, but the fish oil diet did significantly decrease the triglycerides level ($P< 0.05$) in comparison

with Group B. The mixed diet of FO and HC did increase significantly *(P*< 0.05) the level of serum HDL-C and TAS in comparison with group B. In conclusion, this study suggests that king fish oil could act as an important component in the dietary management of atherogenic serum lipids and antioxidative status.

Title	:	Characterization of Green Turtle, Chelonia mydas, Nesting Beaches in Ash-Sharqiyah Region
Student Name	:	Nasser Issa Al Maskari
Supervisor	:	Prof. Anton McLahlan
Department	:	Marine Science & Fisheries

Abstract

The purpose of this study was to describe and classify beaches and to evaluate the most important physical and human-related factors affecting beach selection by the green turtles, *Chelonia mydas*, during the peak nesting season. Three surveys, between July and October 2005, covered around 100 km of coastal area along the Ash-Sharqiyah region of the Sultanate of Oman. The surveyed beaches varied remarkably in terms of physical and anthropogenic characteristics as well as in term of nesting density. Green turtles nested on beaches with different beach aspects, vegetation and ghost crab densities. Green turtles appeared to prefer beaches of shorter length, steeper beach face slope and backed by hills or cliffs. Sand grain size had no significant relationship with nest site selection. However, nesting beaches were characterized by significantly lower sand compaction and well to moderately sorted sand suggesting that better drainage and aeration could be essential factors that made these beaches suitable for nesting activities. Furthermore, some human related factors were also shown to be significantly correlated to the nest site selection: sea turtles selected beaches with few ORV tracks, little artificial lighting, little human litter and limited human accessibility, in other words beaches with little human disturbance. Multiple regression analysis suggested that nesting density was most influenced by beach length, proximity to paved roads and sand compaction. For effective conservation of green turtles, the control of human access to beaches with ideal physical characteristics is thus critical to reduce human impacts on these beaches.

Title	:	Evaluation of a Solar Soil-Water Collector
Student Name	:	Bader Nasser Abdulrab Al Yafie
Supervisor	:	Dr. Hayder Abdel Rahman
Department	:	Soils, Water & Agricultural Engineering

Abstract

Countries in the arid climates of the world are all suffering increasingly from water shortages. In oil producing countries, governments often invest in large desalination plants to overcome water shortages. Desalinated water, nevertheless, is expensive, and people are encouraged to conserve water in their everyday use. This study aims to demonstrate that soil water that has previously been considered irretrievable can be collected, by harnessing the power of the sun to retrieve water from wet soil using a rugged metal collector sunk into the ground. Specifically the experimental goals of this study were to determine the effects of environmental factors on the amount of soil water collected as a condensate in the specially designed solar powered apparatus. These factors included, soil type, air temperature, and soil water content. In addition, properties of the soil water collector were adjusted in order to maximize the amount of condensate. The amount of water collected depended largely on the air temperature and soil water content. In winter 465 ml m^{-2} day^{-1} were collected compared to 1163 ml m^{-2} day^{-1} in summer. However, the initial soil water content was equally important; dry soil tended to yield less condensate than wet soil. Saturated soils yielded 814 ml m^{-2} day^{-1} in winter compared to 1395 ml m^{-2} day^{-1} in summer. The type of soil also affected the release of water from the surface, as a result of differences in soil water release characteristics. The air space between the soil surface and the condensate collecting surface also had an effect on condensate collection within experimental limits, the greater this distance, the more the condensate that was collected. However, the amount decreased over time. The configuration of the condensate collecting surface also had an effect on the amount of condensate obtained; the shallower the angle of the surface, the more condensate was collected. Collection of soil water condensate was feasible under the conditions investigated. The amounts of collected condensate can be of agricultural significance especially in coastal areas when mixed with sea water to support some salt and drought tolerant crop. The designed collector was most effective in the summer, with wet poorly- drained silt soils, on cloudless days.

Title	:	Hydrologic and Hydrogeologic Responses of Springs to Rainfall in Garsias and Arzat Upper Catchments
Student Name	:	Mohammed bin Abdullah Al Amri
Supervisor	:	Dr. Anvar Kacimov
Department	:	Soils, Water & Agricultural Engineering

Abstract

Springs were the main water source before the 1970s for Salalah city and the people who stay in the Dhofar Mountain chain. People after the development of the country are mainly depending on ground water extracted. However, the springs play an important role for providing water for domestic, livestock and agricultural uses. Most of these springs are located in foothills of Jabel Al-Qara and classified as karst springs.

The objective of this study is to identify the hydrologic and hydro-geologic response of Garsias and Arzat spring catchments after rainfall events. Garsias and Arzat springs are located at the elevation of 106, 104 mamsl (meters above mean sea level) respectively. In addition, there are other three major springs: Sahalnawt, Hamran, and Tobruk in the foothills of Jabel Al-Qara. Application of linear potential theory (LPT) to study the Garsias and Arzat springs through the analytical solution by use of Mathematica Software shows that there are no quasi-horizontal flow stream lines and no quasi-vertical potential velocity. The recession curve coefficient of both springs varies between 0.020 to 0.665 1/month for Garsias and 0.0099 to 0.1649 1/month for Arzat spring. The analysis of the Garsias and Arzat springs shows that the observed recession curve gives better fit by use of the Maillet formula compared with the Boussinesq formula. This study estimates the hydraulic properties and characteristics of Jabel Al-Qara aquifers (study area), for example, hydraulic conductivity, and hydraulic head.

The ratio of new water is nearly 20 % of total water that arrives at the spring outlet. Flow type is considered a rapid flow based on the recession curve, whereas using chemical analysis (new water ratio) is diffuse flow. We estimated the total direct recharge of water during the monsoon that reaches the water table between 18.0 to 67.60 % of the total rainfall in Jabel Al-Qara. The monsoon supplies only 29.91 to 45.76 % of the total water discharge

from the springs during one hydrologic year. In addition, we calculated the hydraulic conductivity in Garsias catchments and the results show that it varies between 0.022 to 0.209 m/day using actual observation well data. Whereas by using mathematical model it varies between 0.212 to 7.056 m/day.

The results of the statistical analysis (autocorrelation and crosscorrelations) show no significant relation between the discharge rate and rainfall after two month. The annual discharge rates and annual precipitation calculated by Mathematica software are 1.12×10^6 m^3/year, 345.27 mm/year for Garsias spring and 6.14×10^6 m^3/year, and 204.44 mm /year for Arzat spring.

Generally, spring is a unique source of information for the water assessment in the region. The study of springs leads to further investigation of the Jabel Al-Qara aquifers.

Title	:	Impact of Sedimentation on Recharge to Groundwater at Sahalnoot Dam, Salalah
Student Name	:	Abdullah Mohammed Ali Bawain
Supervisor	:	Dr. S.A. Prathapar
Department	:	Soils, Water & Agricultural Engineering

Abstract

Flash floods occur infrequently in Oman, resulting in losses of fresh water to the sea and deserts. In order to store and increase recharge to the aquifers, the Government of Oman has built 24 recharge dams, 52 storage dams and 6 protection dams across the Sultanate.

Due to high velocities of run-off water, large quantities of sediments are often transported, and deposited in the reservoir of dams. Sediments, which are of finer texture settle when stream velocity is reduced to zero. They lower the rate of recharge by acting as a restrictive layer. Sediment deposits are thick in Wadi beds and low in the flanks of the Wadi. Such differential settlement of sediments add to natural variation of infiltration rate of the native soil, and often reduce the rate of recharge.

In this study, the impact of sedimentation on artificial recharge to groundwater at Wadi Sahalnoot Recharge dam, Salalah, has been studied. Infiltration rates prior to the construction of the dam in 1993 were compared with infiltration rates measured in 2005 at the same locations. The comparison shows that the infiltration rate of the native soils have reduced considerably since the construction of the dam. This is possibly due to the migration of clay and loam particles through macro pores of the native soil profile, during percolation of recharging water. Analysis of the thickness of sediments after flood events in June 1993, May 2002 and September 2004 show that maximum depositions were at same locations after each event, coinciding with lowest positions in the Wadi.

The variation in sediment depth within the reservoir bed contribute to variation in infiltration rate. However, the decline in water level in the reservoir would represent an effective infiltration rate, reflecting the spatial variation in sediment deposition and infiltration rate of the native soil. Therefore, the effective hydraulic properties determining recharge were

determined using a numerical model for unsaturated flow, HYDRUS2D. Changes to free water level following major floods were used to calibrate the model. The sensitivity of the model to calibrated parameters were determined, which was followed by scenario modelling.

Title	:	Rationalization of Groundwater Monitoring Network in South Al Batinah Region, Oman
Student Name	:	Aysha Mohammed Humaid Al Khatri
Supervisor	:	Dr. S.A. Prathapar
Department	:	Soils, Water & Agricultural Engineering

Abstract

In Oman, reliable fresh water resources occur only as groundwater, typically in shallow alluvial unconfined aquifers of the wadi systems that drain the mountains. The scarcity of freshwater resources in the Sultanate makes it essential that groundwater resources are carefully managed and guided by monitoring of water levels in networks of observation bores. Since there is always a degree of uncertainty associated with data collected from groundwater observational monitoring networks, it is essential that the monitoring networks are rationalized periodically. Rationalization of groundwater networks can be achieved by applying geostatistical methods to groundwater level data collected from existing networks.

In this study the groundwater monitoring network in the Southern Al Batinah aquifer has been rationalized using data collected in January 2002, January 2003 and January 2004. A total of 98 bores were considered. Standard deviations of krigged estimates at pre determined nodes were used as the indicator for rationalization. Initially, locations where new bores are required were identified by determining percent gain in information, estimated from standard deviation of krigged estimates. Subsequently, locations of redundant bores were identified by determining percent loss in information, estimated from standard deviation of krigged estimates. It was concluded that two additional bores are required in the north-western part of the aquifer. Groundwater monitoring at four bores within the central part of the aquifer may be discontinued, if resources become limited for monitoring.

Title	:	An Assessment of Groundwater Resources in Salalah Wellfield Protection Zones
Student Name	:	Suad Jaffer Al-Lawati
Supervisor	:	Dr. Mushtaque Ahmed
Department	:	Soils, Water & Agricultural Engineering

Abstract

The Sultanate of Oman has seen a rapid development over the past three decades. As a result, water demand has risen in line with the development and improved standard of living. Many of the freshwater production wellfields are located in rapidly developing areas, where land values are high and frequent requests are received from landowners for various development activities. To protect the limited groundwater resources, Wellfield Protection Zones (WPZs) legislations were implemented in the Sultanate. The objective was to protect groundwater destined for the wellfields from contamination, over abstraction, saline water intrusion and adverse land development.

This study aims to determine whether groundwater in the Salalah wellfield protection zone is contaminated from existing development projects and whether the groundwater is of acceptable quality for drinking. Investigation of groundwater levels and salinity levels were part of the study. To achieve the aims of the study, a combination of collation, analysis of piezometric data and water quality data for Salalah wellfield protection zones were undertaken. A survey of existing development in red zone(the most critical zone) was done.

The study concludes that the net discharge from the production wells do not significantly caused changes in water levels in the aquifer. Water levels in the monitoring wells in the red and orange zones rose by 1.71m due to their location directly under the area of front of Jabel Al- Qara. Water levels declined by 0.13 m in the area where the large farms are located. Water quality parameters remained stable and comply with the Omani standards for drinking water. For example, Calcium level was 132 mg/l. Magnesium, Chloride, Sulfate, Nitrate and Fluoride some times approached the highest desirable levels but did not exceed them. They were at 27, 248, 42, 28 and 0.30 mg/l respectively. Trace metals, hydrocarbon concentration were within Omani drinking standards and no Coliform or E.Coli bacteria were detected in all of the groundwater samples. On the other hand, salinity in some

monitoring wells increased marginally from 980 µS/cm in 1996 to 1100 µS/cm in 2004 in fresh groundwater zone. Whereas it increased from 4400 µS/cm in 1996 to 5000 µS/cm in 2004 in some wells in brackish groundwater zone. Increase in salinity was observed from 5000 µS/cm in 1996 to reach to 11000 µS/cm in 2004 in some wells in the closest part to the coastline. The increases in salinity may due to agricultural return flow, mixing of saline water from the deeper part of the aquifer or direct saline water intrusion from the area especially in the wells closest to the coastline.

The study recommends adoption of best management practices for Salalah WPZ and other WPZs in the Sultanate.

Title	:	Biological Treatment of Omani Household Greywater Using Sequencing Batch Reactor (SBR) Technology
Student Name	:	Aamna Yasser Abdullah Al-Abri
Supervisor	:	Dr. Mushtaque Ahmed
Department	:	Soils, Water & Agricultural Engineering

Abstract

Shortage of water in arid and semi arid regions leads to a search for other sources such as reuse of domestic wastewater. Greywater is a component of domestic wastewater, which is defined as all the wastewater that drains from the household except the toilet water. In this study a sequencing batch reactor is used to treat greywater which is an activated sludge process that operates in time rather than in space and consists of five different phases: fill, react, settle, draw and idle. Samples of greywater were collected from an Omani household. All the experiments were conducted in a 25 bench scale plexiglass single tank reactor with one discharging port placed at the bottom of the reactor. The reactor was of cylindrical shape, 37 cm in height and 29 cm in diameter and the volume prior to fill was 20 liters. The experiment showed the capability of the sequencing batch reactor in treating greywater with reduction of chemical oxygen demand (COD) ranging from 75% to 94%, and percent removal of suspended solids (SS) ranging from 65% to 100%. The obtained results are very satisfactory and meet the Omani standards where the maximum value of COD allowed is 150 mg/L and the highest value obtained for post treated water is 124 mg/L. In term of SS, the maximum value allowed by Omani standard is 15 mg/L and about 80% of SS values obtained are below this limit. The biomass seeding of the system ranged from 30% to 35%. The operational modes that were investigated in this study were 0.5 hr fill and 4.5 hrs react, 1hr fill and 4 hrs react, 1.5 hrs fill and 3.5 hrs react, 2hrs fill and 3 hrs react, and 2.5 hr fill and 2.5 hrs react. A higher loading of organic matter gave better results than using low loadings. As organic loadings increased the substrate removal efficiency, also increased. The excellent performance of SBR was achieved when the fill time was 40% of the track time at operational mode of 2 hrs fill: 3 hrs react. An excellent settlement characteristic of sludge was obtained through use of SBR and the problem of sludge bulking or foaming was absent.

International Collaboration

International Collaboration

New collaborations have been established with several institutions and universities as follows:

No.	Organization	Type of Cooperation	Contact Dept / Extent of Benefit
1.	Challenge Program for Water and Food, CGIAR, C/-IWMI, Sri Lanka	Collaborative research and capacity building	Soils, Water and Agricultural Engineering (SWAE)
2.	Regional Center for Urban Water Manage-ment, Teheran, Iran	Collaborative research and capacity building	SWAE
3.	Wageningen Agricultural University, The Netherlands	Collaborative research and capacity building	SWAE
4.	International Rice Research Institute, Los Baños, Philippines	Collaborative research and capacity building	SWAE
5.	Australian Center for International Agricultural Research, Australia	Collaborative research and capacity building	SWAE
6.	International Atomic Energy Authority, Vienna, Austria	Collaborative research and capacity building	SWAE
7.	National Centre for Oceanography, UK	Scientific and research cooperation	Marine Science and Fisheries (MSF)
8.	University of Reading, UK	Collaboration on research projects in pest and disease control	Crop Sciences (CROP) / Joint supervision of PhD students
9.	University of Pretoria, South Africa	Collaboration on mango disease control	CROP /Joint supervision of postgraduate students
10.	National University of Ireland	Farmer decision making	CROP /Joint super-vision of PhD student
11.	University of Reading, UK	Collaboration on research projects in pest and disease control	CROP /Joint super-vision of PhD students
12.	University of Pretoria, South Africa	Collaboration on mango disease control	CROP /Joint super-vision of postgraduate students
13.	National University of Ireland	Farmer decision making	CROP /Joint super-vision of PhD student

International collaboration . . .

No.	Organization	Type of Cooperation	Contact Dept / Extent of Benefit
14.	MATFORSK (Norwegian Food Research Institute), Norway	Measurement of allicin in fresh and dried garlic; and functional foods	Food Science and Nutrition
15.	University of Kassel Germany	Collaborative research	Animal & Veterinary Sciences (AVS) / Joint supervision of postgraduate students
16.	University of Hohenheim Germany	Collaborative research	AVS / Joint super-vision of postgraduate students

Publications in 2006

Publications in 2006

Eighty-two refereed journal publications were recorded for the year 2006. Figure 1 highlights the number of refereed publications for the period 1995-2006. This represents published refereed journal papers only, and excludes manuscripts in press, accepted or under preparation. One significant work resulted in an application for a patent.

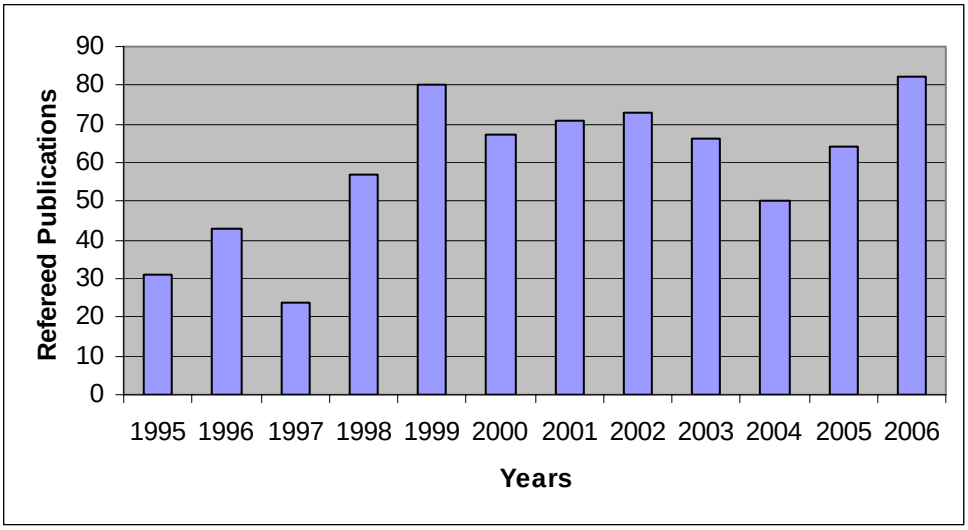

Figure 1. Annual numbers of refereed journal publications, 1995-2006.

Also published in the year 2006, were 2 books, 1 book review, 3 book chapters, 62 conference proceedings/papers presented, 7 conference/poster abstracts, 15 papers presented in local/foreign workshops/seminars, 3 popular articles, 8 reports and 1 manual.

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