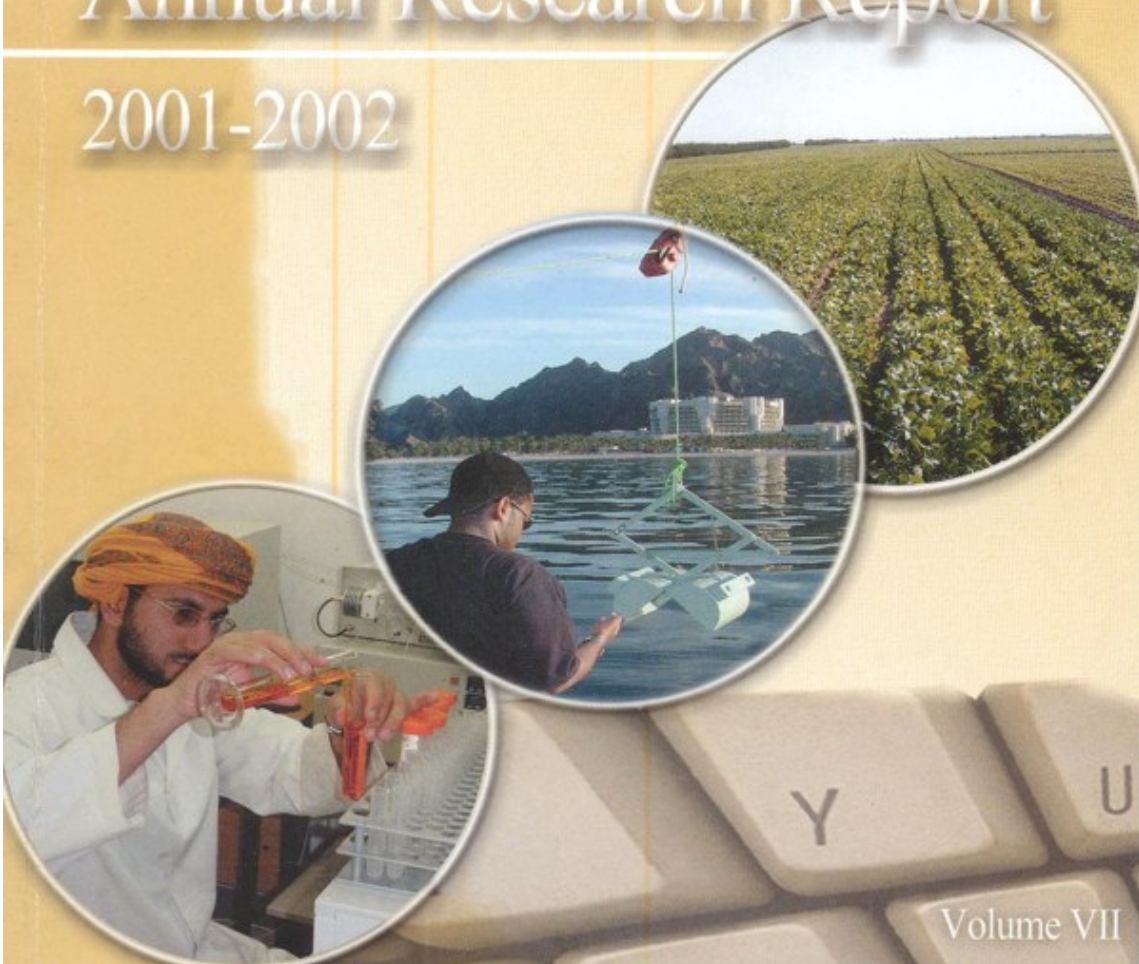




Sultan Qaboos University
College of Agricultural and Marine Sciences

Annual Research Report

2001-2002



Volume VII



Sultan Qaboos University

College of Agricultural and Marine Sciences

**Annual Research Report
2001 – 2002**

Volume VII

FACTS & FIGURES

- **RO 1,431,993 Total College Research Budget**

- **71 Refereed Journal Publications in 2001**

- **76 Active Research Projects**

- **16 Externally Funded Projects**

- **New Projects Awarded in 2002**
 - **2 SQU Strategic**
 - **15 SQU Grants**

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Foreword

The 2001/2002 academic year was an exciting period for research in the College of Agricultural and Marine Sciences (CAMS), highlighted by the awarding of a large number of internal and external grants and contracts by the fostering of strong links with industry. The College continued in its desire to be the center of excellence in agricultural and fisheries research in Oman and the Near East Region. The College's aim is to conduct basic and applied research in a broad range of disciplines that have immediate and long-term benefits resulting in the promotion of sustainable agricultural and fisheries development.

Several achievements served to strengthen the research and postgraduate programs in the College. Firstly, the College was awarded two strategic research and development projects financed from His Majesty Research Fund. Secondly, more than 80 postgraduate students at the M.Sc. level are actively involved in supporting the research programs. Eight students graduated in 2001.

By the Grace of God, our efforts in this regard are sustained by the generous support and sincere encouragement of the University's President, H.E. Dr. Saud Bin Naser Al-Ryami and the Vice President Dr. Hamed Bin Suliman Al-Salmi. It is with great pleasure that on behalf of all members of the Research Committee, we express our deepest and most sincere sense of gratitude and appreciation to them.

Hamed Bin Said Al-Oufi
Assistant Dean for Postgraduate Studies and Research

Research Committee

Hamed Said Al-Oufi

Chair

Dept. of Marine Science & Fisheries

Imad Haffar

Co-chair

Dept. of Bioresource & Agricultural Engineering

Eugene Johnson

Dept. of Animal & Veterinary Sciences

Houcine Boughanmi

Dept. of Agricultural Economics & Rural Studies

Mushtaque Ahmed

Dept. of Soil & Water Sciences

Humphrey Esechie

Dept. of Crop Sciences

Stefan Kasapis

Dept. of Food Science & Nutrition

Arnold Sutterlin

Dept. of Marine Science & Fisheries

The Year in Review

Research is an integral element of the College of Agricultural and Marine Sciences (CAMS). Accordingly, it has been the College's objective not only to provide training for the country's young people, but also to develop and disseminate basic and applied research that will result in the continuous improvement of the quality of life.

In the research program, CAMS is presently conducting a total of 76 research projects and contracts, 15 of which were awarded in 2002 (Tables 3 and 4). The total budget for these projects is RO 1,431,993 (Table 1).

The scope and status of all projects funded through His Majesty's Research Fund are described in Table 2, while Table 3 reflects the scope and status of projects funded by Sultan Qaboos University in 2002. Abstracts of the new projects awarded to the College in 2002 are illustrated in pages 28-42. Sixteen SQU funded projects were completed in the reporting year (Table 4).

Table 1. Summary of Research and Development Projects Held by the College in 2002.

Source	Number of Projects	Total Budget (RO)
SQU funded projects		
• Completed	16	86,000
• Continuing	26	185,100
• Approved in 2002	15	87,160
• Strategic projects	3	344,000
Externally funded projects		
• Continuing	13	690,004
• Approved in 2001	3	39,729
Total	76	1,431,993

Table 2. Research and Development Projects Funded through His Majesty's Research Fund.

No	Title of Research	Principal Investigator	Year started	Amount (RO)
1.	Fish product development for export and the local markets.	S. Kasapis	2002	96,000
2.	Seawater greenhouse development for arid climates: An innovative approach for water desalination and crop production.	S. Sablani	2002	88,000
3.	Improvement of date palm production and dates quality in the Sultanate of Oman.	O. El Mardi	2001	167,000

Table 3. Internally Funded Research and Development Projects Awarded in 2002.

No	Title of Research	Grantee (s)	Amount (RO)
1.	Assessment of greywater reuse potential in Oman.	M. Ahmed	9,180
2.	An examination of the life-history parameters of the common grouper, <i>Cephalopholis hemistiktos</i> , and its application to fisheries management.	J. McIlwain	10,650
3.	Scientific and technological aspects in the development of confectionery and ice cream products using mixtures of gelatin and <i>k-carrageenan</i> .	S. Kasapis	10,800
4.	A quantitative assessment of WTO negotiations on agriculture and food security in Oman.	H. Boughanmi	3,450
5.	Analytical modeling of multiphase flows in porous media.	A. Kacimov	3,000
6.	Solute transport in porous media: Physical, analytical, and numerical modeling.	S. Al-Jabri	6,150
7.	Assessment of concentration polarization in brackish and sea water reverse osmosis system.	M. Goosen	4,080
8.	Assessment of high hydrostatic pressure blanching technique in food processing.	S. Sablani	3,900
9.	Textural properties and consumer preference:	M. Rahman	4,100

No	Title of Research	Grantee (s)	Amount (RO)
	Identifying optimum quality characteristics of dried dates by rheological profile analysis related to texture.		
10.	Development and testing of a computer controlled, cyclic misted forced ventilation system for cooling dairy cows.	I. Haffar	4,000
11.	Determination of commercial meat products quality in the Sultanate of Oman.	O.M. Gaafar	8,650
12.	Collection and evaluation of native and exotic germplasm of important crops of Oman.	A. Al-Maskri	9,600
13.	Heavy metals in coral skeletons.	M. Claereboudt	2,550
14.	Environmental tolerance limits and physiological adaptations of the Arabian pup fish, <i>Amphanius dispar</i> (Ruppell) to extremes in temperature, salinity and dissolved oxygen.	A. Sutterlin	3,750
15.	Identification of anti-microbial substances in fresh commercially sold pasteurized milk.	A. S. Kumar	3,300
Total			87,160

Table 4. Internally Funded Research and Development Projects (1999-01).

No	Title of Research	Grantee (s)	Grant dates, start-end	Status	Amount (RO)
1.	Analytical determination of hydraulic characteristics.	A. Kacimov	1999-01	Completed	1,300
2.	Assessment of mineral statues and strategies for supplementation in Omani livestock.	O. Gaafar	1999-01	Completed	6,500
3.	Analysis of traditional animal production systems in Oman.	L. Zaibet	1999-01	Completed	5,000
4.	Use of local materials in feeding Omani cows.	O. Gaafar	1999-01	Completed	7,500
5.	Combating soil salinity at SQU Agri. Expt. Station.	P. Cookson	1999-01	Completed	6,500
6.	Evaluations of two breeding programs for reproductive mgmt. in lactating dairy cows.	A.S. Kumar	1999-01	Completed	5,500
7.	Development of solar technology for drying dates.	D. Ampratwum	1999-01	Completed	5,000
8.	Rational use of pesticides for potato production in Oman.	M. Deadman	1999-01	Completed	2,400
9.	Investigation into phytoplasma diseases of alfalfa in Oman.	A.J. Khan	1999-01	Completed	7,500
10.	Kinetics of vitrification and / or crystallization in processed food products containing date ingredients.	S. Kasapis	1999-01	Completed	7,000
11.	Influence of nearshore hydrodynamics on the variability in larval supply and recruitment of coral reef invertebrates.	M. Claereboudt	1999-01	Completed	7,500
12.	An evaluation of regional proteins resources for use in aquaculture feeds.	S. Goddard	1999-01	Completed	1400
13.	Collection and production of seeds of important crops in	A. Al-Maskri	1999-01	Completed	9,500

No	Title of Research	Grantee (s)	Grant dates, start-end	Status	Amount (RO)
	Oman.				
14.	Investigation on the ground water quality.	M. Ahmed	1999-01	Completed	2,500
15.	Consumptive use of greenhouse crop utilizing low quality water.	H. A. Rahman	1999-01	Completed	1,400
16.	Electro-kinetics to manage nitrate movement in irrigated soil.	S. Al-Rawahy	1999-01	Completed	9,500
17.	Measurement of rates of potential methanogenesis in sedimentary-gathering behind recharge reservoirs.	P. Cookson	2000-02	Final	400
18.	The role of agriculture in Oman's economic development: a general equilibrium framework.	H. Boughanmi	2000-02	Final	3,500
19.	Characterization of vitamin B12 deficiency in Omani goats.	E.H. Johnson	2000-02	Final	5,000
20.	Enhancement of quality and storage stability of dried abalone using freeze-drying technology.	S. Sablani	2000-02	Final	12,000
21.	Insecticidal properties of sub-tropical plant extracts against insects.	K. Azam	2000-02	Final	5,375
22.	Screening exotic potato germplasm for adaptation to the heat-stressed environments of Oman.	I. Khan	2000-02	Final	5,100
23.	Chlorophyll metering in forage corn.	H. Esechie	2000-02	Final	8,535
24.	Managing Witches' Broom disease of lime.	O. El Mardi	2000-02	Final	3,925
25.	Fish product development for export and the local market.	S. Kasapis	2000-02	Final	12,000
26.	Structural changes of biological materials during drying: a framework of developing quality fish products from raw	M. Rahman	2000-02	Final	12,000

No	Title of Research	Grantee (s)	Grant dates, start-end	Status	Amount (RO)
	agricultural materials.				
27.	Development of a novel test for the rapid determination of protein quality for aquafeed ingredients.	S. Goddard	2000-02	Final	9,800
28.	Computer-assisted training in the marine sciences.	M. Claereboudt	2000-02	Final	5,000
29.	Gill net selectivity in the sardine fishery.	H. Al-Oufi	2000-02	Final	4,650
30.	Identification of antimicrobial substances in fresh commercially sold pasteurized milk..	A.S. Kumar	2000-02	Final	2,315
31.	Development of a solar thermal-powered pumping system.	S. Al-Rawahy	2001-03	Second	8,400
32.	The development of e-commerce in the agro-food industry.	H. Boughanmi	2001-03	Second	8,400
33.	Production, reproduction and clinical manifestations induced by low dietary levels of vitamin B12 in Omani goats.	E.H. Johnson	2001-03	Second	9,600
34.	Improvement of carcass and meat quality characteristics of Omani goats.	I. Kadim	2001-03	Second	5,400
35.	Investigation and optimization of humidification and dehumidification processes in greenhouse to produce fresh water.	J. Perret	2001-03	Second	8,400
36.	Introduction and evaluation of lime somatic hybrids potentially resistant to Witches Broom Disease of lime.	I. A. Khan	2001-03	Second	9,500
37.	Development of transgenic potato cultivars expressing d-endotoxin gene resistant against potato tuber moth.	A. J. Khan	2001-03	Second	10,400
38.	Use of CT scanning for visualizing stress responses in roots.	M. Deadman	2001-03	Second	4,800

No	Title of Research	Grantee (s)	Grant dates, start-end	Status	Amount (RO)
39.	Quality assessment of fresh yellow-tuna at low temperature storage.	N. Guizani	2001-03	Second	9,400
40.	Roles of light and copper in the development of off-flavour in milk..	F. Consolacion	2001-03	Second	2,400
41.	Prevalence of salmonella in/on eggs in the Sultanate of Oman.	A. Mothershaw	2001-03	Second	6,400
42.	Nutritional status of Omani population.	S. Iqbal	2001-03	Second	12,400
Total					271,100

In 2002, CAMS was awarded two strategic projects from His Majesty's Research Fund. The first entitled, "Development of fish products for export and the local market", was funded with a total budget of RO 96,000. the second entitled "Utilization of greenhouse technology for water desalination and crop production" was funded with a total budget of RO 88,000. The College had been awarded RO 167,000 in the previous year to enhance the production, quality and utilization of date palms. This generous support will aid the College to foster its research and aid it in gaining recognition for agricultural and fisheries research in the years to come.

To enhance our research activities and to increase dialogue and information flow between our College and its counterparts in other countries, we seek to facilitate cooperation with regional and international research centers. In this regard, a number of joint research projects have been conducted successfully with universities in different parts of the world (e.g. University of Arizona and United Arab Emirates University).

CAMS is engaged in research projects that cover a broad range of disciplines in the areas of agriculture, food systems, animal production and marine sciences and fisheries. The aim is to seek scientific and practical solutions for problems that are associated with the development of the agricultural and fisheries sectors. At present, researchers at the College hold 16 projects sponsored by external agencies such as the Fisheries Research Fund, Petroleum Development Oman (PDO), and the Middle East Desalination Research Center (MEDRC). (Table 5).

Table 5. Externally Funded Research and Development Projects.

No	Title of Research	Grantee (s)	Agency	Grant / Contract Dates, Start-end	Year in Grant / Contract	Amount (RO)
1.	Management of Oman's Kingfish Fishery.	H. Al-Oufi	Fisheries Research Fund, MAF	1999-02	Third	271,000
2.	Aquafeed development from by catch.	S. Goddard	Fisheries Research Fund, MAF	2000-03	Second	160,000
3.	Elasmobranchs fisheries of Oman.	H. Al-Oufi J. McIlwain	Fisheries Research Fund, MAF	2000-04	Second	98,000
4.	Management of Red palm weevil.	K. Azam	UAE/SQU	1997-01	Final	28,000
5.	Oil field water research.	H. Esechie & M. Ahmed	PEC, Japan	1998-01	Completed	
6.	Production water clean-up and reuse: Demonstration of high value crop growth using solar dew technology.	M. Goosen I. Haffar A. Al-Maskri A. Al-Nuaimi	Oman/ PDO	2001-03	First	15,300
7.	Study on processes controlling nitrate contamination of groundwater and development of nitrate management guidelines.	M. Ahmed	MWR	2000-03	Second	5000
8.	Assessment of the innovative freezing-melting process for desalination of sea water in the Gulf countries.	M. Rahman & M. Ahmed	MEDRC	2000-03	Second	20,000
9.	Effects of processing	O. Gaafar	Fisheries	1997-01	Final	60,000

No	Title of Research	Grantee (s)	Agency	Grant / Contract Dates, Start-end	Year in Grant / Contract	Amount (RO)
	on quality of local dried sardines and its use as animal feed.		Research Fund, MAF			
10.	A serological study of contagious caprine pleuropneumonia.	E. Johnson	CIRAD EMVT European Union	Nov 1997 open	Fourth	Lab Support
11.	Reed bed technology for production water cleanup.	M.F.A. Goosen	PDO, Oman	2001-03	First	8,700
12.	Seawater greenhouse development.	S. Sablani M. Goosen W. Shayya	MEDRC	1998-02	Final	8,000
13.	Reed bed treatment and reuse of oil production water.	H. Rahman H. Esechie P. Cookson A. Kacimov O. El Mardi A. Al-Mahraki	PDO, Oman	2000-03	Second	26,594
14.	Evaluation of a water saving high-absorbency copolymer.	H. Rahman S. Al-Rawahy	EPDC, Japan	2000-02	Second	3,310
15.	Evaluation of mykoplant for Oman agriculture.	P. Cookson H. Rahman	Inst. Inov. Tech., Germany	2000-01	Final	1,500
16.	Brine disposal methods used in PDO operated desalination plants.	M. Ahmed	PDO, Oman	2001-02	Final	15,729
Total						729,733

The College has strong partnerships with the Ministry of Agriculture and Fisheries, and the Ministry of Municipalities, Environment and Water Resources in conducting joint research. In addition, this year was

characterized by strong industry involvement accompanied by a significant increase in the level of funding. This type of collaboration is vital for the survival of the College as an effective research center.

The College is actively involved in reaching out internationally to a large audience, in sharing ideas and adapting new developments. For the past seven years, the College has published its refereed *Journal-Agricultural Sciences*. In an effort to disseminate new ideas and research findings, the College organizes symposiums and international conferences. For example, in January 2001, the College hosted the International Conference on Fisheries, Aquaculture and Environment in the NW Indian Ocean with participation from 25 countries. The proceedings for the conference were published in early 2002. A conference on ground water contamination is planned for January 2003. Similarly, the College organizes a number of workshops which involve participants from government ministries, private companies and from outside Oman. For example, the Department of Marine Science and Fisheries organized a workshop on Tropical Fish Ageing on January 2002. Three scientists from Iran participated in this workshop amongst 12 others from Oman. In May 2002, the Department of Food Sciences and Nutrition organized successfully a workshop on Food Safety and Hygiene. Similarly, the Department of Soil and Water Sciences organized a workshop on Ground Water Modeling in February 2002.

Apart from its leading edge research activities in agriculture, food systems and marine sciences, CAMS is also committed to transferring knowledge and skills to the broader food systems community through its research and graduate programs. The aim of the postgraduate program, for example, is to produce high caliber researchers who will maintain and enhance the country's position in the regional food systems research and development. For these students, CAMS provides access to advanced laboratory facilities and leading researchers in their field of study.

Record of Activities

Department of Agricultural Economics and Rural Studies

The research agenda for the Department of Agricultural Economics and Rural Studies continued to focus on three major areas: Macro-level, Micro-level and the Sectoral-level. Dr. Houcine Boughanmi is conducting a project to develop a general equilibrium model to investigate the link between the agricultural and the non-agricultural sectors of the economy. The expected output is to identify the appropriate sectoral and economy-wide policies to enhance the agricultural contribution to national economic growth. The results of this research project are summarized in a paper submitted for publication in SQU Agricultural Sciences Journal. The project is expected to end by spring 2002.

A study on traditional farming systems in Jebel Al Akhdar region, with a special emphasis on small animal producers is also conducted by Dr. Houcine Boughanmi. The financial support for this project ended on 2001 but work continued to collect information on the project site and follow-up some of the activities implemented during last year, using the department resources. Two refereed papers resulted from this project, one presented in international conferences and the other submitted for publication in an international journal. The final report of the project is now under writing and is due this summer (2002).

Dr. Houcine Boughanmi and Prof. John Waelti conducting a study on quantitative assessment of WTO negotiations on agriculture and food security in Oman. This is a new project which addresses the issue of food security within the context of further trade liberalization imposed by the new trading system. The first year of the project will be devoted to 1) a critical review of the Oman proposal to join WTO with respect to specific binding and reduction commitments and 2) literature review on the implication of WTO on developing countries' agriculture.

Department of Animal and Veterinary Sciences

The Department launched a major research project that is directed at elucidating the myriad effects of vitamin B12 deficiency in indigenous goats. Other joint projects include studying the effects of additives to feeds to improve meat quality.

Dr. A.S. Kumar's research involves evaluating the effects of prostaglandins on reproductive management of dairy cows, developing breeding programs for sheep and goats, studying the effects of vitamin B12 deficiency on goats and evaluating camel reproductive tracts.

Dr. O. Gaafar has continued work in the areas of growth biology of indigenous breeds of livestock but he is branching into two different areas. In the first area, he is beginning to investing farming system within the Sultanate. The work will be done in tandem with the Department of Agriculture Economics and Rural Studies. The second study will study the genetics of indigenous breeds of livestock in Oman.

Dr. E.H. Johnson's research includes various aspects in the study of the host parasite interaction. Specific areas include caprine contagious pleuropneumonia, cryptosporidiosis, the effects of seasonal variations on the caprine immune system and the clinical and immunological manifestations associated with vitamin B12 deficiency in goats as well as sub-clinical mastitis and dientamoebiasis.

Dr. I. Kadim's research is directed towards evaluating carcass, meat quality characteristics, animal nutrition, feed evaluation and vitamin B12 deficiency in goats. His research also involves the effects of enzymes and ascorbic acid on meat quality and production.

Department of Bioresource and Agricultural Engineering

Dr. Sablani carried out experiments to measure adsorption isotherms, freezing point temperatures, and thermal conductivity. The adsorption isotherm results indicated the monolayer moisture content of 7.47% (d.b.). Initial freezing point of abalone decreased from -0.4 to -15.9°C when its moisture content decreased from 80 to 34% (w.b.). Freeze drying experiments indicated that the shelf temperature of -10°C was optimal for freeze-drying. Thermal conductivity of abalone increased from 0.49 to 0.72 W/mK as temperature increased from 20 to 80°C . Dr. Sablani also visited Salalah to collect valuable and scientific information on sun drying of abalone.

Dr. Ampratwum conducted two tests with prototype dryer in July and August 2001 for the production of dried dates. On the average, dates with an initial moisture content of 50.4% were dried to 19.5% in 20.5 hours. The final moisture content of the dates was close to the level of consumer appeal.

Dr. Perret is investigating the potential of a humidification/dehumidification process to produce fresh water from seawater/brackish water in greenhouse. He has design and installed a cooling and condensing circulation system in one of the greenhouses at the AES. He has also installed a state-of-the-art data logging system with several temperature and relative humidity sensors within the greenhouse.

Dr. Rahman conducted experiments to investigate the changes of endogenic bacterial counts in minced tuna during dry-heating (convection air-drying) and dry-heating (heating in a closed chamber) as a function of temperature. The D-values decreased from 2.52 to 0.26 hr for moist-heating and 2.57 to 0.34 hr for wet-heating, respectively when temperature was maintained constant within 60 to 140°C . He found that the heat resistance characteristics of microorganisms in fresh tuna mince was not dependent on the changing medium moisture content. The z-values were found 144 and 46°C for temperature within 60 to 100°C and 100 - 140°C , respectively.

Department Crop Sciences

In a study completed by Prof. Khaja Azam, the leaves and seed extracts of eight sub-tropical plants indigenous or introduced to Oman were tested at different concentrations for their insecticidal properties against whitefly and leaf miner. The study, entitled "Insecticidal Properties of Subtropical Plant Extracts against Insects", revealed that the highest mortality rate in leaf miner was recorded in extracts of *Azadarachta indica* with above 90% in the concentrations of 1, 2 and 3%. Part of the results was presented at the International Conference on Agriculture, Science and Technology in Beijing, China in November 2001.

Dr. Humphrey Esechie is working on "Chlorophyll Metering: An Innovative Approach to Nitrogen Management in Forage Corn". This project, which is now in the second phase, aims to improve N management practices to reduce the potential for nitrate leaching. Initial results have shown that chlorophyll meter readings varied between 52 and 60 SPAD units and were highly correlated ($r = 0.96$) with leaf N concentration and with extractable chlorophyll content ($r = 0.94$). Analysis of dry matter yield in the N treatment plots as well as the N reference plots are in progress and will be used to compute the *N sufficiency index*.

Dr. Iqrar Khan in his project, "Introduction and Evaluation of Lime Somatic Hybrids Potentially Resistant to Witches' Broom Disease of Lime", is attempting to develop lime and related citrus hybrids resistant to this disease. The research work, with collaboration from the University of Florida Citrus Research and Education Center, has progressed according to set objectives.

Dr. Michael Deadman is researching on "The Use of CT Scanning to Visualize Plant Roots Under Biotic and Abiotic Stresses". Despite restricted access to the CT scanner at SQUH, he has achieved a 3-dimensional reconstruction of the entire root system, which was recently displayed in an international conference.

Dr. Mahdi El-Mardi is conducting a project on "Management of WBDL via Biotechnological Approach". Micrografting of healthy lime on sweet orange, sour lime and grapefruit has shown some success. However, grafting infected lime on the top graft dried out, possibly because of weakly developing infected phloem. Field grafting gave variable results.

Dr. Jamal Khan has succeeded in raising disease free potato ex-plant through leaf tissue culture. In his project, "Development of Transgenic Potato Cultivars Expressing d-Endotoxin Gene Resistant Against Potato Tuber Moth (*Phthorimaea operculella*) Insect", leaves of regenerated potatoes will be used for the transformation of CryIAc gene with suitable promoter for dicots and *Agrobacterium* as vector.

The University of Kassel in Germany is collaborating with Dr. Ahmed Al-Maskri in his project, "Collection and Evaluation of Native and Exotic Germplasm of Important Crops of Oman". Two PhD students working on the project are being co-supervised by Dr. Al-Maskri. He is also writing a comprehensive paper titled "Wheat in Oman".

Department of Food Science and Nutrition

Dr. Stefan Kasapis has completed a study on “Vitrification and/or Crystallization Kinetics in Processed Food Products” containing date ingredients. Samples have been analyzed using small and large deformation rheology (ARES & Instron), and calorimetry (DSC). A state diagram of temperature vs. date solids was constructed providing vital clues of the liquid-like, rubbery, crystalline and glassy consistency of dates containing foods. These results will be used in another study entitled “Improvement of Date Palm Production and Dates Quality in the Sultanate of Oman” which will fully develop food processing operations of date containing food products.

Dr. Stefan Kasapis is also working on “Fish Product Development”, an undertaking which entails the quality control of fish. His project aims to take advantage of minced fish from underutilized species which are discarded due to consumer unfamiliarity, boniness, ‘bad names’ and unpleasant looks of the fish. It is aimed to develop a range of value-added fish products like fish burgers, sausages, fingers, and breaded fillets. The immediate target is to develop a fish freshness index (the so called K-value) for color, chemical composition, and texture/sensory that will guide product development on a sound technological basis.

Dr. Nejib Guizani reported preliminary results of a research project on “Quality Assessment of Fresh Yellow Fin Tuna at Low Temperature Storage”. The results indicated that temperature is a critical variable for the quality and safety of fish. Fish shelf-life, freshness and histamine levels were best observed at 0°C and 8°C compared to 20°C. Future analysis will include increased sample size and tuna caught at different periods of the year.

Dr. Sheikh Saud Iqbal is researching the nutritional status of different age groups and strata of Omani population under the title “Assessment of Biochemical Indicators of Vitamin Nutriture of Male and Female University Students in Oman”. All necessary requirements to set up the project have been finalized and the study has commenced in earnest.

Dr. Ann Mothershaw is conducting a project on the “Prevalence of Salmonella in/on Eggs in the Sultanate of Oman”. The highlight of the study is to identify the most frequent genera contaminating eggs on sale from local retailers in Oman. This will determine the total viable microbial count of eggs stored at refrigerated and room temperature. In addition, it is aimed to identify any other potential health risks from consuming eggs besides salmonellae. Eggs from Oman, Holland, and China are now being

purchased on a weekly basis and sampled for salmonellae. The results demonstrate that although low temperature storage inhibits the growth of the contaminating organisms it also increases the survival time. The study is also extended to investigate the role of packaging on the survival of microorganisms on the surface of the eggs.

Dr. Frisco I. Consolacion reported on the initial results of a research project entitled "Roles of Light and Copper in the Development of Off-Flavour in Milk". The initial study on the effect of fluorescent and ultraviolet light, copper and polyethylene bottle on the development of lipid oxidation in milk indicated high thiobarbituric acid reactions. A modified technique using gas chromatography-mass spectroscopy (GC-MS) will be used instead of the initial technique of gas chromatography method to provide not only the quantity but also the molecular structure of the volatile aldehydes and ketones. This experimental approach should increase the accuracy of the determination of the volatile compounds. The new approach will commence as soon as the required chemicals are received.

Department of Marine Science and Fisheries

Research activities in the Department continued in 2001/2002 in three main fields i.e. fisheries, aquaculture and marine biology. These are focused in areas of stock assessment, fisheries co-management, reef fish biology, fish and shrimp nutrition, aquafeed development, fish physiology, ecosystem modeling and biological oceanography.

Dr. Hamed Al-Oufi and other researchers in the department are conducting a study on the management of Oman's kingfish fishery. This project, funded at 271,000 R.O. was started in November 1999. The objectives of the project are to collect baseline data on kingfish biology and its fishery. The gathered information will then form the scientific basis for a national kingfish management plan. Fieldwork was largely completed in 2001 and a detailed interim report published. Laboratory work, data analysis and final report writing is scheduled for 2002. Dr. Al-Oufi is also studying the selectivity of gillnets used in the sardine fishery in Oman. Extensive fishing experiments were carried out during 2001/2002 using 10 experimental fishing nets of different mesh sizes and hanging ratio.

Dr. Stephen Goddard is working on aquafeed development. This project, funded by the Fisheries Research Fund at 160,000 R.O. was started in December 2000. The project involves an investigation into the potential utilization of fisheries by-catch as a major ingredient in fish and shrimp feeds. Collaborative work is in progress with commercial fishing companies and a fishmeal and oil plant for the production and analysis of fishmeals. An experimental unit for testing aquafeeds has been developed under the project.

Dr. Hamed Al-Oufi and Dr. Jennifer McIlwain are undertaking a project on the Elasmobranch fisheries of Oman. This project, funded at 98,000 R.O. commenced activities in December 2000. The overall objective of the project is to produce a national shark management plan based on species distribution, stock assessment, utilization and conservation measures. Field work was initiated in 2001 to gather information on species distribution, fishermen's landings and levels of utilization.

Dr. M. Claereboudt is studying the influence of near-shore hydrodynamics on the variability in larval supply and recruitment of coral reef invertebrates. The project aims at elucidating the oceanographic and biological mechanisms responsible for the variability in coral reef organisms. The underwater climate of the north of Oman was found to have two distinct seasons with rather abrupt changes in the form of wind

driven upwellings. The upwelling waters are low in temperature, poor in dissolved oxygen and rich in nutrients. Dr. M. Claereboudt is also developing a web-based instructional media in marine sciences. This project aims at developing new on-and offline multimedia instructional materials to provide up to date and geographically relevant teaching media in marine sciences. The project is in progress.

Department of Soil and Water Sciences

Drs. Peter Cookson and Anvar Kacimov completed a project on 'Modeling and Testing 2- and 3-Dimensional Flow Patterns in Near Surface Soil Profiles'. Two mathematical models were developed to account for evaporation losses due to partial coverage of the soil surface. The models yielded useful predictions of changes in pressure head potentials at the soil surface with the size of opening in the hydrophobic layer. It was also observed that application of subsurface hydrophobic polymer reduced evaporation and salt accumulation in overlying soil.

Dr. Peter Cookson, as Principal Investigator, continued work on the project 'Monitoring, Modeling and Combating Soil Salinity at the SQU Agricultural Experiment Station'. Salinity contour maps have been drawn using data collected from selected grid wise sampling. Soil salinity in one of the greenhouses was also assessed during the growing season of a vegetable crop. Research efforts were concentrated on designing and testing in the laboratory of a novel method for combating soil salinity.

Dr. Peter Cookson is also conducting research on the measurement of rates of potential methanogenesis in sediment gathering behind recharge reservoirs. The objectives of this project are, i) to determine variations in methane production from sediments, both spatially and over time, and ii) to identify organic and inorganic limitations to methane production in sediments. As part of the project, soil description in and around the basin of one reservoirs and study of methanogenesis from some anaerobic soils in Oman have been completed.

Dr. Salim Al-Rawahy developed and evaluated an in-situ electrochemical technique for managing nitrate movement in soil irrigated by a buried drip system. Field results show greater nitrate accumulation near the anode in the electrified lysimeters than in non-electrified lysimeters thus maximizing nitrate utilization by crop while minimizing nitrate leaching into the groundwater by using electro-drip. Increased acidity was also observed which increased nutrient solubility in the region near electrified drip tube. Dr. Salim Al-Rawahy has started preliminary works on the development of a solar thermal powered pumping system.

Dr. Anvar Kacimov successfully completed a project on 'Analytical and Numerical Determination of Hydraulic Characteristics'. Novel analytical solutions for determination of key hydraulic characteristics (conductivity, flow and transport parameters) for flows in porous and fractured media were developed. Problem of seawater intrusion into a coastal aquifer was addressed. Canal shapes of minimal seepage losses have been identified.

Dr. Mushtaque Ahmed is investigating the groundwater quality in agricultural areas of Batinah. The project involves assessing water, nutrient and pesticides use and their optimization by the application of models. Realization of project objectives will be helpful in developing strategies to minimize the risk of groundwater pollution in agricultural areas of Oman. A pesticides use survey was conducted and groundwater samples have been analyzed for various quality parameters. Laboratory experiments were conducted to understand Dimethoate movement in the soil profile. Models have been used to estimate travel time of selected pesticides to groundwater.

Summary of Projects Awarded in 2002

Assessment of Greywater Reuse Potential in Oman

M. Ahmed¹, A. Al-Maskeri², K. Al-Busaidi³ and A. Al-Belushi¹

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Duration: 3 years

Budget: RO 9,180

Summary

Greywater is the water that has been used for washing dishes, laundering clothes, or bathing. In other words, except for toilet wastes (blackwater), all water draining from a household is greywater. Studies have shown that significant differences exist between greywater and blackwater. Under most conditions, it would be possible to reuse greywater with little treatment. This will have positive environmental and economic benefits. Considering the severe water shortage problem in Oman, reuse potential of greywater needs to be investigated. Among other things, this project aims to quantify greywater production in Omani households, characterize important water quality parameters of greywater, design simple treatment systems and investigate likely impact of greywater irrigation on crop growth and yield. Guidelines for greywater reuse in Oman will also be recommended.

**An Examination of the Life-History Parameters of the
Common Grouper, *Cephalopholis Hemistiktos*,
and its Application to Fisheries Management**

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and Marine Sciences, P.O. Box 34, Al-Khod 123, Sultanate of Oman

Duration: 2 years

Budget: RO 10,650

Summary

To date there has been no investigation into the life history parameters of grouper species commonly caught by traditional fishermen in Oman. These parameters are fundamental in developing population models, which are used to describe the dynamics of a fished species, a fishery or ecosystem. They include estimates of age, growth, mortality and reproductive output. One species of grouper, *Cephalopholis hemistiktos* (known locally as Hamour) has been chosen as the model for a study of grouper stocks in Oman. It is the dominant species at landing sites and fish markets from Musandam to Salalah and is the most abundant serranid seen during underwater visual surveys. An investigation of the age and sex structure of this species will be undertaken at two locations, Muscat and Masirah. These locations are 450 km apart and subject to very different environmental conditions. To test whether exploitation alters the age and sex of this species, two sites will be chosen at each location that represents a gradient of fishing pressure. Fish will be collected at each location once only using a regime of standardized fishing effort. Ageing will take place in the newly established ageing facility at the Department of Marine Science & Fisheries. Gonads will be subject to histological examination to determine the sex structure of these populations and whether this species undergoes hermaphroditism. The frequency of spawning, occurrence of mature and immature fish and age at first reproduction will be estimated from fish purchased every month from the local fish markets. Finally, to determine whether different stocks of *C.hemistiktos* occur in Oman, fish samples will be collected twice (summer and winter) from Musandam, Muscat, Masirah and Salalah. Bulk analysis using ICP-AES techniques will determine if the elemental composition of the otoliths is significantly different between these four locations.

**Scientific and Technological Aspects in the Development
of Confectionery and Ice Cream Products Using
Mixtures of Gelatin and κ -Carrageenan**

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

Duration: 3 years

Budget: RO 11,800

Summary

The aim of this research is to provide fundamental understanding of the effect of thermodynamic incompatibility of high sugar protein-polysaccharide systems in relation to the structural and mechanical properties that affect multicomponent food systems. Since proteins and polysaccharides are used in many industrial applications, ingredient producers and food manufactures wish to better understand the behavior of mixed gels in order to optimize their use, and identify new textures and applications. The project will evaluate the main physico-chemical properties of multicomponent gels in terms of phase-separation which is hypothesized to occur in the absence of favorable interactions thus determining the structural, textural and sensory properties of polymer mixtures (Walkenstrom & Hermansson, 1996). The emphasis, at the beginning, will be on gelatin and κ -carrageenan, two popular ingredients in the manufacture of high solids food products. A quantitative approach for the mixed system will distinguish between polymers which form part of the molecular network and those which are merely contained within the network structure in terms of concentration, and consider the effect of solvent redistribution between phases within the gel (Morris, V., 1986). This understanding of mixed systems in a high sugar environment will allow a wide array of textural characteristics and opportunities for engineered products to be obtained. The output of the project in the form of scientific publications and technical reports will be available to the Omani food industry in an effort to help understand the behavior of food products, which are available for export and the local market.

A Quantitative Assessment Of WTO Negotiations on Agriculture and Food Security in Oman

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Duration: 3 years

Budget: RO 3,450

Summary

Oman has joined the WTO on October 10, 2000 and is expected to adjust its national policies, mainly trade policies, in line with WTO principles of multi-lateral trading system. As a net food importing country, Oman could be adversely affected by the higher international food prices as developed members countries are required to reduce substantially agricultural subsidies. There is, hence, a clear priority for Oman to adopt reforms stimulating domestic production. The overall objective of this project is to investigate and quantify the effects of WTO trade and non trade rules on the Omani agricultural and food sector, and identify the appropriate policies that addresses the issue of food security within the context of further trade liberalization imposed by the new trading system. The assessment of WTO implications will be undertaken using an economy-wide approach that links food security to the overall performance of the economy.

Analytical Modeling of Multiphase Flows in Porous Media Based on the Theory of Free Boundary Problems

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²Department of Mathematics and Statistics, College of Science,
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Duration: 2 years

Budget: RO 3,000

Summary

Mathematical modeling of multiphase flows in aquifers containing macrovolumes of fluids with contrasting physical properties (density, viscosity and conductivity) will be done based on the methods of complex analysis, asymptotic methods, computer algebra, etc. New explicit analytical solutions will be derived assuming sharp interfaces between zones occupied by different fluids. Hydrocarbon traps and stringers in monoclines and anticlines floating on the surface of seeping groundwater will be delineated. Different regimes of waterflooding (constant rate, cyclostationary and aperiodic drives) will be addressed with an emphasis on upconing, slumping and superpropagation. Discharge of fresh groundwater through a tilted beach surface and over a heavy sea water tongue will be investigated. Practical implications for petroleum engineers, petrogeologists and water resource managers will be elaborated.

Solute Transport in Porous Media: Physical, Analytical, and Numerical Modeling

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

Duration: 3 years

Budget: RO 6,150

Summary

Experiments in the Agricultural Station based on pulse injection of tracer solutes through a system of surface emitters and detection of the concentration breakthrough curves and stroboscopic pictures will be conducted. Interpretation of Time Domain Reflectometry obtained data will be done with dispersion and mass exchange coefficients as key constants used in the advective dispersion analytical and numerical conceptual models. Pulses of infiltration from recharge dams and wadi beds to the water table and the consequent formation and decay of groundwater mounds will be investigated analytically. Plumes, drawdowns and capture zones in aquifers subjected to hydrodynamic impacts of vertical, horizontal and slanted wells operating under constant rate and pulse regimes will be examined by analytical and MODFLOW modeling.

Assessment of Concentration Polarization in Brackish and Sea Water Reverse Osmosis Systems

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and R. Al-Belushi¹**

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²Department of Mechanical and Industrial Engineering,
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Duration: 3 years

Budget: RO 4080

Summary

Global water resources are under increased pressure as a result of extensive population and economic growth. To help alleviate the water shortage problem, desalination using reverse osmosis (RO) membranes, for example, is being employed with greater frequency for producing fresh water from brackish and sea water. During the initial period of operation, however, concentration polarization (i.e. solute buildup at the membrane surface) is one of the primary reasons for flux decline. The long term objective of our project is to improve the performance of RO desalination systems. The short term objective is to increase our understanding of concentration polarization phenomena in seawater and brackish water RO systems through experimental analysis and mathematical modelling. Specific objectives are: evaluate the influence of trans-membrane pressure and type of feed salinity (i.e. sodium chloride solution, seawater, brackish water) on permeate flow rate and its salinity; assess effect of spacer thickness in spiral wound units on permeate flow and its salinity; and estimate membrane parameters using an analytical osmotic pressure model for seawater and brackish water. In the long term this research will aid in improving the performance of RO desalination systems through increased membrane lifetimes, increased fresh water fluxes across the membrane, decreased operating costs, and decreased membrane fouling.

Assessment of High Hydrostatic Pressure Blanching Technique in Food Processing

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Duration: 3 years

Budget: RO 3,900

Summary

Conventional heating methods are used for blanching of fruits and vegetables in order to inactivate enzymes before further processing of foods in canning, freezing and drying. A high hydrostatic pressure method will be assessed as an alternate method for blanching for fruits and vegetables so as to exploit its unique advantages such as less environmental pollution and retention of many important quality factors, over conventional thermal processes. Thermal and pressure inactivation kinetics of enzymes will be determined for this purpose. The quality (i.e. color, texture.) of the blanched product will be assessed. Thermal and pressure treated products will be subjected freezing and dehydration so that the transport (heat and mass) processes can be studied. The quality of dried products will be evaluated in terms of color, rehydration ratio, texture and porosity. The output of this project will be published in the form of scientific publications and technical reports. The potential use of this high hydrostatic pressure technology for the food processing industry in Oman will be evaluated.

Textural Properties and Consumer Preference: Identifying Optimum Quality Characteristics of Dried Dates by Rheological Profile Analysis Related to Texture

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Duration: 3 years

Budget: RO 4,100

Summary

The current economic vision of diversification of national income has given priority to the development of renewable resources in the agriculture sector by utilization of high priced quality date products. At present dates are usually sun dried by the farmers in open air to preserve them. In some cases they also use solar drier. The uncontrolled weather conditions during open sun drying or solar drying reduces the drying efficiency and produce low quality date products. Thus drying methods are being used in the local industry is in its infancy and produces very low quality products. However, wide ranges of high quality products could be developed applying innovative drying technology and optimum drying conditions. It is important to assess the value added date products by measuring sensory, textural, structural, and rheological quality attributes. The objective of this study is to develop methods of assessing structural, and rheological quality attributes related to texture of dried dates. Helium gas pycnometer, mercury porosimetry, Texture Profile Analyzer, Scanning Electron Microscopy, GC-MS, and HPLC will be used to study these properties. Initially convection air-drying, freeze-drying, and vacuum-drying available at SQU will be used in this project. Further trials will be conducted on other innovative driers when available at SQU.

Development and Testing of A Computer Controlled, Cyclic Misted Forced Ventilation System for Cooling Dairy Cows

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Duration: 3 years

Budget: RO 4000

Summary

Dairy production in Oman is rapidly and steadily developing into an industry that emphasizes quantity and quality as well as economic sustainability. However, the hot and humid climate in which dairy cows are raised possesses a great challenge to the industry as heat stress reduces feed intake and consequently milk yield and exposes cows to immense physiological stress. This research aims at developing and testing a misted air ventilation system for cooling dairy cows. The system provides intermittent misting and forced ventilation through computer-controlled algorithms to ensure maximum cooling and minimum consumption of water. The algorithms are stimulated by a number of environmental parameters collected by sensors in the dairy shed as well as data on the nutritional, production and physiological status of the cows. The research involves a variety of expertise with agricultural engineering, information technology and animal physiology skills.

Determination of Commercial Meat Products Quality in the Sultanate of Oman

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Duration: 3 years

Budget: RO 8,650

Summary

The project aims to evaluate the quality of some meat products commercially available in the Omani market. These include imported and local mutton, lamb, beef and poultry. Samples will be collected from the mostly available fresh, chilled, and frozen products from supermarket outlets in greater Muscat area. Full carcasses, cuts, boneless, mince and processed meats will be sampled. Appraisal will include study of quality attributes, health hazard residues and contaminants and microbiological load. Routine laboratory methods and machine read kits will be used for categorization of quality in the laboratories of the departments of Animal & Vet. Sciences and Food and Nutrition at SQU.

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

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Duration: 3 years

Budget: RO 9,600

Summary

Agriculture is the primary occupation of the people of Oman. It has been undergoing modernization which includes the introduction of seeds of exotic varieties. The continuing exotic introductions have enabled large scale of production of modern varieties. However, the uncontrolled introductions have brought unforeseen diseases and insects and have led to a withdrawal of farmer's attention from traditional crop varieties. Land races of crops sustained agriculture in Oman for centuries and now face extinction. These races hold exceptional adaptive advantage which should be preserved and propagated. This project aims at 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 ends by 31st December 2001. We have developed some protocols to provide a basis for indigenous seed production of well adapted local and exotic land races and cultivars. One research paper is accepted, several conference presentations have been made and three manuscripts are under preparation. Postgraduate students are involved in this research (M.Sc and Ph.D) 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.

At the end, guidelines shall be prepared for seed storage, seed health testing and maintenance. A scientific basis shall be provided to initiate a seed registration and certification program in Oman.

Heavy Metals in Coral Skeletons

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Duration: 2 years

Budget: RO 2550

Summary

This study aims at elucidating the potential of reef corals to record variations in heavy metal concentrations in the environment. Corals skeleton will be analyzed using ICP-AES (Inductive coupled plasma atomic emission spectrometry) for increased concentrations various metals related to either human activities (Cu, Pb, Cd, Vn...) or naturally occurring sources of metals (ophiolites rich in Mn, Ni, Cu...).

Sections of massive corals will also be analyzed to study time series of metal incorporation in skeletal material over time (0-30years).

**Environmental Tolerance Limits and Physiological Adaptations of
the Arabian Pup Fish, *Amphanius Dispar Dispar* (Ruppell) to
Extremes in Temperature, Salinity and Dissolved Oxygen**

A. Sutterlin

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Duration: 2 years

Budget: RO 3,750

Summary

In the Qurum Mangrove Reserve in Muscat, Oman, the Arabian pupfish (family cyprinodontidae) inhabits small, warm, hyper saline pools that are low in dissolved oxygen. In view of their small body size and elevated temperature, the metabolic rate of these fish is expected to be quite high. These factors coupled with the energetic cost of regulating the osmotic pressure of internal blood plasma well below that of ambient water (by active salt secretion by gills), places further metabolic demands on these fish which would not be tolerated by most other species. Attempts will be made in this study to define the tolerance limits and metabolic scope (oxygen consumption) of these fish under a variety of environmental conditions. Attempts will also be made to reveal the adaptive physiological and behavioural mechanism enabling these fish to cope with these rather extreme conditions. Contributions to the basic understanding of the physiology of this species could have practical implications for the use of this fish in mosquito control, as a bioassay animal for water quality assessments and as a source of heat shock or stress induced proteins useful in the production of transgenic fish for aquaculture.

Identification of Antimicrobial Substances in Fresh Commercially Sold Pasteurized Milk in Oman

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Duration: 3 years

Budget: RO 3,300

Summary

Antimicrobials given in subtherapeutic levels in feed are credited with having contributed to lower costs of meat, milk and eggs, as well as an overall improvement in animal health. However, this practice of routinely using antimicrobial agents in animals have led to the development of antibiotic resistant reservoirs of organisms. Many antibiotics routinely used for treatment of human infections are also used in animals therapeutically or for growth promotion. Antibiotic resistance constitute a public health hazard, primarily through the increased risk of treatment failure and induction of allergies. Mastitis in dairy cattle is routinely treated with several combinations of antibiotics. Milk withdrawal times are dependent upon the type of antibiotic used, as well as the route of administration. Unfortunately, the milk producers in Oman do not strictly follow these recommendations. Preliminary studies undertaken by the Department of Animal and Veterinary Sciences have demonstrated that a number of commercially available milk samples sold in Oman exhibited antimicrobial activity against a variety of bacteria. Due to the potential hazardous effects of antibiotics to human health, studies must be undertaken to detect the presence and the frequency of occurrence of antimicrobial substances in milk. The results of this study will aid in establishing the seriousness of this human health issue in Oman.

Publications in 2001

The year 2001 was an exciting one for researchers in terms of the number publications. A total of 71 refereed publications were recorded in 2001, an increase of 3 per cent compared to that of 2000 (Fig. 1). This represents either published or in press refereed papers, while accepted and submitted manuscripts were not considered in this reporting period.

Figure 2 highlights the number of refereed publications per faculty during the period 1994-2001. An average of two refereed publications per faculty were recorded in 2001, which is similar to that achieved in 2000. The substantial number of refereed publications has put the College in a prestigious position in comparison to other universities and government organizations.

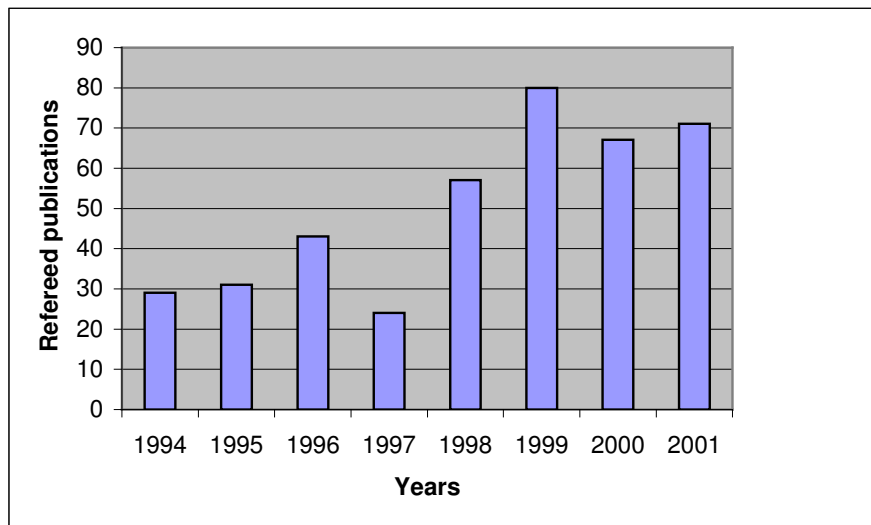


Figure 1. Comparative refereed publications output over the past 8 years.

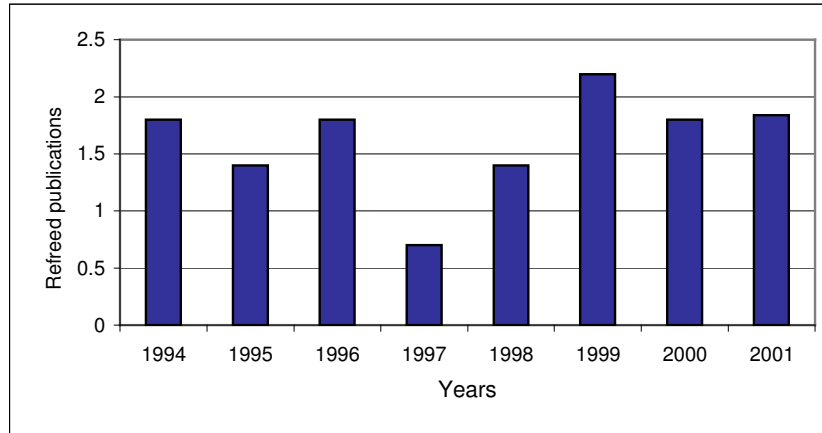


Figure 2. Comparative refereed publications per faculty for 1994-2001.

On the other hand, researchers were actively involved in regional and international conferences. The outcome of these participations reflected in the number of non-referred publications which represent conference presentations and abstracts. An overview of the total publications (refereed and non-refereed) by researchers in CAMS is presented in Figure 3.

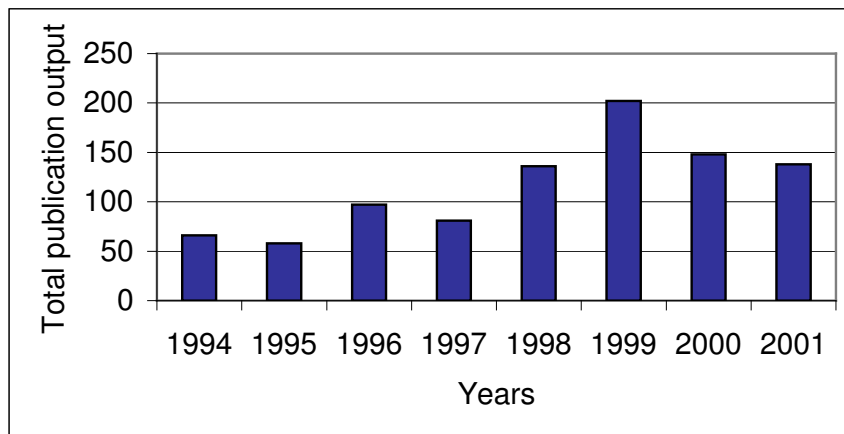


Figure 3. Comparative total publications output for 1994-2001.

Researchers output in terms of book chapters and technical reports were remarkable, with 11 book chapters and 8 technical reports respectively produced by the College's faculty in 2001. In addition to that, faculty participated in 35 local and international workshops in 2001. Two patents were registered as well in this reporting period.

List of Refereed Journal Publications

1. Ahmed, M., A. Arakel, D. Hoey and M. Coleman. 2001. Integrated Power, Water and Salt Generation: A Discussion Paper. *Desalination* 134 (2001): 37-45.
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14. Early, R.J., O. Mahgoub and C.D. Lu. 2001. Energy and protein utilisation for maintenance and growth in Omani ram lambs in hot climates. I. Estimates of energy requirements and efficiency. *The Journal of Agricultural Science (Cambridge)*, 136: 451-459.
15. Early, R.J., O. Mahgoub and C.D. Lu. 2001. Energy and protein utilization for maintenance and growth in Omani ram lambs in hot climates. II. Composition of tissue growth and nitrogen metabolism. *The Journal of Agricultural Science (Cambridge)*, 136: 461-470.
16. Early, R.J., O. Mahgoub, C.D. Lu, A. Ritchie, A.S. Al-Halhali and K. Annamalai. 2001. Nutritional evaluation of solar dried sardines as a ruminant protein supplement. *Small Ruminant Research* 41 (1): 39-49.
17. Esechie, H.A., A. Al-Saidi and S. Al-Khanjari. 2001. Effect of sodium chloride salinity on seedling emergence in chickpea. *Journal of Agronomy & Crop Science* (In Press).
18. Esechie, H.A., V. Rodriguez and H.S. Al-Asmi. 2001. Effect of seeding rate on yield of irrigated wheat (*Triticum aestivum*) in the Batinah Coast of Oman. *Crop Research* (In Press).
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22. Goosen, M.F.A., S.A. Al-Hinai and S.S. Sablani. 2001. Capacity building strategies for desalination: activities, facilities and educational programs in Oman. *Desalination* 141 (2): 181-190.
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