Value adding to Seafood by Application of Modern Drying Techniques

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FISHERIES RESEARCH & DEVELOPMENT CORPORATION

CENTRE FOR FOOD TECHNOLOGY

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NON-TECHNICAL SUMMARY

The milestones for this project have been met. A marketing study was conducted prior to the technical experimentation. This study, "**Evaluation of the market for dried seafood**", was produced as the first milestone report and was intended to identify suitable prospects for experimentation. Both domestic and overseas markets were analysed and a number of suitable species were identified. Market information on dried seafood is not readily available to seafood processors so when the market report compiled for the first milestone was produced many requests were made to the project researchers from industry for copies. To satisfy the demand for this report it was sent to the Australian Seafood Extension and Advisory Service for promotion. At the time of this report over 20 copies had been sold.

A total of 16 species of seafood have been trialed using the Heat Pump Drier (HPD). Information has been generated for 5 companies from the species trialed. These are C.A.Impex, Le Mer Marketing and Consulting Pty LTD, Alimarine, South Pacific Dried Foods and Qld Sun-Dried Seafoods. Of the species dried there were several which did not lend themselves to quick and easy drying. Large and dense samples such as Australian salmon and large mullet were impossible to dry whole. Even with splitting, case hardening begins within a few hours limiting the effectiveness of the HPD. Large sized cuttlefish with cuttle present also showed some sign of case hardening. These types of product would require some planning as to the organisation of a processing line to ensure the maximum efficiency of the equipment, quality of product desired and production output.

Product appraisal of HPD samples has been obtained for prawns, fish maw, split squid, scallops and pearl meat. The quality of prawns produced by heat pump drying is very high but the wholesale value quoted at A$17 per kilogram is insufficient for this product to be economically viable under Australian conditions. Raw material costs overseas can be as low as $1/kg.

Fish maw produced from Australian barramundi can become a valuable export commodity. A most recent price obtained from Taiwan by one of the industry collaborators found that high quality dried fish maw was A$81/300gm, fried dried fish maw was A$11/300gm and fish maw processed in a sauce and vacuum packed was A$41/600gm. Fish maw is offered for sale in Australian shops at $112 per kilogram. One wholesale price was obtained at A$50 per kilogram for large fish maw and A$17 per kilogram for small. This difference in pricing due to size has great impact on the viability of drying fish maw. While fishermen do not want to spend time sorting what is to them a waste product too many small maw in a shipment can lead to low returns and even losses after drying. The quality is also effected by the handling on board the fishing boat. The blood vessels and fatty tissue present on the raw material should be removed before freezing to prevent staining and textural damage. Current prices for raw material of A$9-15 combined with recoveries of 20-40% make drying of small fish maw a risk rather than an option. A careful balance of the different sizes is required for processing to be viable.

There are large processing factories in Asia dedicated to producing dried squid. The product is produced cheaply, in a variety of forms and in large volumes. This makes it difficult to compete with this product under Australian conditions. This form of drying can be successful if the dried squid is to be further processed into soups or meals or as a dietary supplement for prawn spawning stocks.

The increase in the amount of pearl culture in Australia in recent years will mean that good supplies of pearl adductor muscle will become available in the near future. Dried pearl meat is held in high regard by consumers and good prices can be obtained. As this was originally a waste product from the industry no raw material costs so far have been available but pearl producers who retain material and either dry in house or contract dry using other processors should expect good prices as retail prices as high as A$500/kg have been obtained for the dried product. Recoveries (from the raw material to the dried product) were obtained between 12% for raw and 30% for cooked pearl meat.

There are a number of other species such as whelk and other small molluscs which when dried are in demand in Asia but at present under or not utilised in Australia. These can fetch prices as high as A$200/kg. Recoveries from the raw material of 30% were obtained after drying.

PROJECT BACKGROUND

There is an enormous market throughout the world for dried seafood, many of which command high prices. Six major markets have been identified by FAO. The Japanese market is very large and is growing slowly (12.8% from 1980 to 87). Markets in Hong Kong (526t in 1993-4) and Spain, Germany, Italy are big and growing while that in Portugal is very big and growing fast. Except for Portugal, these countries are in the top 10 biggest importers of fisheries products. While fresh and frozen seafood dominates world markets there is still an increasing demand for dried seafood. Although a large part of this trade is in large salted, dried fish such as cod (bacalao) and similar gadoid species which Australia could not supply, there are markets for a diversity of products which could be produced here.

Australia also deals in a number of different, quite valuable dried seafood products as described in the table below.

Exports and imports of dried seafood (Source: Australian Bureau of Statistics)

Commodity	Exports $ 1991/92	Exports $ 1992/93	Imports $ 1991/92	Imports $ 1992/93
Dried cod	NA	NA	816 268	745 476
Fish fillets (dried, salted or in brine)	40 426	28 309	1 069 650	1 486 612
Dried fish (excluding cod, fillets and smoked)	1 640 677	2 560 416	2 487 499	3 434 280
Fish liver and roes, dried, smoked, salted or in brine	474 099	1 102 373	110 517	87 158
Cuttlefish, octopus and squid, frozen, dried , salted or in brine	325 207	412 333	16 919 765	17 470 387
Molluscs and aquatic invertebrates, frozen, dried , salted or in brine	75 060 416	120 501 718	17 584 115	12 698 788

A further breakdown of the information in these categories can be (will be) purchased from the Australian Bureau of Statistics as part of the initial market studies. For some of the minor items of interest the world market for dried sea cucumber (beche-de-mer) in 1988 was over $6 million.

The Centre for Food Technology has been contacted by Australian processors who are having difficulty drying this product. The company NSW Abalone (ACN 051 066 490) is investigating the use of the heat pump drier as a method of product diversification for abalone and sea urchin roe and has requested processing information from Centre for Food Technology. A letter of support for this grant proposal has been included.

Another industry supporter is interested in drying mullet gizzard. The demand for this product seems to be unlimited. Another is interested in drying scallop wastes to make high quality feeds (see attached letter).

Technologies
In general, Australia finds it difficult to compete where the production techniques are labour intensive. Where Australia has a competitive edge is in efficient technologies.

One such example is in the advance in drying technology afforded by the heat pump drier. The heat pump drier is essentially an insulated cabinet through which air is pumped at a controlled temperature and moisture content. Some of the water vapour removed from the product by the air is condensed and the heat recovered and recycled. This comparatively dry air is returned over the product and thus the cycle continues. Heat pump drying is more efficient and less destructive to the product and there are substantial cost savings to be gained.

This technology allows products to be dried at relatively low temperatures in areas of high humidity and or high ambient temperatures. This greatly increases the seasonal and geographic range over which products can be dried. Furthermore, it means that products can be dried more rapidly under controlled conditions which prevent spoilage. There is a major advantage in drying at low temperatures to conserve the natural flavour and form of the product. Another important factor is that the drying process makes efficient use of the energy supplied, since much is recovered and recycled. Heat pump drying is `environmentally friendly' and has lower labour costs.

Industry enquires
In the past year the NSIS and Centre for Food Technology seafood group have received enquires on drying of seafood products at an average of one a week. These enquires originate from all states and are typically to do with the drying of small volume high price products. Other enquires concern existing drying processes and design of `appropriate driers', kilns or smokers.

It is obvious from these enquires that there are market opportunities for quality products. It is also obvious from the Centre for Food Technology general background knowledge that there is a need for applied research in the area of drying specialty seafood to make high value products.

Centre For Food Technology initiative
As part of a general program to produce high quality dried food products for export to Asia, the Centre for Food Technology has acquired several new types of drying equipment - a heat pump drier, a vacuum dehydrator, microwave attachments for the latter and a vacuum fryer capable of producing the new generation snack foods popular in Japan. All these technologies shorten drying times, reduce damage to the product, use lower process temperatures, are energy efficient and retain the shape and desirable flavour and colour of the product to a greater extent than existing technologies. These are cost competitive technologies.

Award
As a result of work done on the design and efficiencies of heat pump drying, an award from the Department of Primary Industries and Energy has been presented jointly to the Centre for Food Technology, the University of Queensland Gatton College (UQG) Department of Food Science & Technology and the South East Queensland Electricity Board (SEQEB). The award, the 1993 National Energy Award for Industry category, is to recognise and promote efficient and innovative uses of energy.

There are now 30 heat pump driers used in the agricultural sector in Queensland which highlights the acceptance of this technology by industry. The object of this current proposal is to explore the application of this efficient technology to seafood drying to ensure this sector of primary industry is not left behind and that it capitalises on the technology for the benefit of the seafood industry.

Integration with other RDCs
Over the last 3 years, a successful joint research program on heat pump drying has been carried out by the Centre for Food Technology and the University of Queensland, Gatton College, under grants from

ERDC and RIRDC. This has provided information on energy efficiencies and drying conditions for a small number of food products and indicated the huge potential for the technology in a wide range of food and other products. This research has provided an excellent base on which to build a broad, integrated drying research program. Such a program would include **an expansion of the capabilities of heat pump drying** for use with liquids and in conjunction with processing technologies such as spray drying and extrusion cooking, and to operate under a wider temperature and humidity range; development of **new drying technologies and protocols** such as vacuum frying and microwave-assisted vacuum drying; determination of the **optimum drying parameters and product specifications** for a wide range of food and other products; and **marketing studies** related to both the dried products and the technology.

Drying technology centre
A proposal to form a Drying Technology Centre incorporating the Centre for Food Technology and the University of Queensland (Gatton College) is being forwarded through the Energy Research and Development Corporation to the FRDC (see Appendix).

Implications for this project

This project has been prepared as a stand-alone project. It will, however, fit into the overall program of the proposed Drying Technology Centre and will call on its facilities and expertise.

PROJECT NEED

This technology has considerable potential in the industry to help fulfil the need to obtain greater returns from the available catch, and to utilise by products and under-utilised species. The obvious need to extend the application of heat pump drying to include seafood products arises from two sources. The first is from the direct enquires by the industry itself to NSC and AUSEAS wanting information on better ways to dry product. A supporting letter from the Manager of the NSC is attached. Within the last year, the AUSEAS alone has received enquires on drying from ten individual processors, from four states, concerning the technology, design and operation of dryers. The second comes from the all-encompassing need to make the most of the available catch and convert it into high value products.

Correct drying of seafood to consistently produce a uniform product is not an easy task. Solar drying is hard to control and hot air drying is inefficient in energy use since heat is lost in the exit gases. Conventional driers produce high air temperatures and have difficulty providing uniform air flow over the product. The consequent large differential between the air and the product causes case hardening on the surface of the material by drying the surface more rapidly than moisture can migrate from the inside.

Heat pump driers can maintain both the humidity and temperature of the drying air irrespective of ambient air conditions.

PROJECT OBJECTIVES

- To apply the heat pump drying process to seafood
- Produce appropriate samples of heat pump dried seafood for evaluation
- Explore the use of other modern drying technologies to seafood

The first two objectives have been met. The most appropriate product to be applied to alternate drying technology to heat pump drying is fish maw. As this product is fried after drying it would have been suitable to conduct experiments using the vacuum fryer. Unfortunately supplies of good quality raw material were impossible to obtain so that this method could not be investigated. The conduction of taste panel appraisal of this product was also prevented because of supply problems at the time the experiments were planned (October/December 1996). The time originally dedicated to other technologies has been utilised to increase the range of species trialed and to improve the techniques applied to dry seafood.

Project Milestones

1 July 1995	Obtain market information on dried seafood from available sources. Survey industry for by-catch or by-products suited to drying	completed
	Survey of market for suitable product forms and product characteristics	completed
	Evaluate market and species information	completed
	Identify and select species most appropriate for drying	completed
	Start drying trials on selected species	completed
1 January 1996	Identify industry collaborators	completed
	Continue drying trials on selected species according to seasonal availability	completed
	Progress report	completed
1 July 1996	Continue drying trials and refine processes for key products. Assist collaborators in development	completed
	Progress report	completed
	Complete drying trials and compile final report	completed

METHODS

The Heat Pump Drier

The heat pump drier (**HPD**) operates with a maximum air speed of 1.7 m/sec and temperature of 55°C. While it does heat up the air in the drying cabinet it cannot cool below atmospheric conditions so that on very hot days the operating temperatures may rise above those set for the machine. There are humidity sensors present to monitor the moisture levels of the air as it enters the drying cabinet and after it exits. The efficiency of the unit is such that there is usually little difference between the two positions. There is no control of the condenser to maintain a specific humidity. This facility is available in the most recent versions of the heat pump drier produced by the manufacturer of the present equipment. This development would allow continual drying without the need for equilibration, although the time required to operate the machine would be much greater.

The cabinet contains a section where racks are mounted on load cells. These continually measure the weight of the product being dried. There are racks in the other section to take up to 100kg of material. The load cells carry 5 aluminium frames fitted with flyscreen mesh and each of these are called a **row** of sample numbered 1 from the top to 5 on the bottom for reporting purposes. They hold up to one kilogram and the maximum the load cells can take is 5 kilograms. The load cells and humidity detector are connected to a mounted datalogger which stores the data being generated. Another independent datalogger is used to record the temperatures during drying. Thermocouples are arranged to monitor the internal temperature of product, the cabinet air and the external or ambient air. Apart from the load cells there is provision to take 60 stainless steel **trays** with either mesh or solid bases. These can hold twice the capacity of the load cells.

Case hardening can occur when the rate of water removal from the surface exceeds the movement of moisture from the internal tissue to the surface. The surface then dries to an impervious skin or case, which acts as a barrier to further drying. To avoid the extreme levels of this condition the drying is halted before the drying curve flattens out. **Equilibration** is then carried out by softening the surface during refrigerated storage. This is required to allow the moisture levels of both inside and surface tissue to become equal. A period of drying followed by one of equilibration was tested during the drying trials of some products. The equilibration involved the shut down of the fans, heater and condensor of the HPD and the product was kept at room temperature. This sequence was repeated for several cycles and was called **intermittent** drying.

Water Activity

The amount of water present in a product can be measured two ways. The traditional method is to weigh a sample, place it in a desiccator containing silica gel and then into a high temperature oven, usually at 90°C. As the water evaporates it is bound by the silica gel. At the end of the drying in the oven the sample is weighed and the amount of weight lost, expressed as a percentage of the original weight, is the **moisture content** of the sample. The method used for moisture analysis was No. 952.08 (modified) from the Association of Official Analytical Chemists (AOAC).

The other method used for determining water content is to determine the **water activity** (a_w). This is a measurement of the water particles in a product that are not chemically or physically bound. The a_w or Equilibrium Relative Humidity (ERH) is the ratio of the water vapour pressure above any sample to the water vapour pressure of pure water at the same temperature. The a_w of pure water is 1.000 while no water is 0.000. Microbiologists recognise that a_w rather than total moisture content governs the growth, survival rate, death, sporulation and toxin production of microorganisms. The instrument used by this investigation to measure a_w was an Aqualab model CX2 (Decagon Devices Inc., Pullman, Washington 99163). Method No. 978.18 from the Association of Official Analytical Chemists (AOAC) was used to determine water activity.

Bacterial count

A 10g sample, obtained aseptically, was placed in a sterile stomach bag with 90mL of sterile 0.1% peptone (Difico 0885-01-9) diluent. The sample was homogenised for one minute in a Colwell Stomacher 400 (Steward Medical, London).

Mesophilic counts were performed by spread plating 0.1mL of homogenate on nutrient agar (BBL 11476) and incubating at 30°C for 72 hours. Serial dilutions covering the range 10^2 to 10^6 were used in duplicate. The counts were expressed as colony forming units per gram (cfu/g).

Product evaluation

Samples of heat pump dried seafood were presented to four Asian supermarkets in Fortitude Valley for evaluation. The managers were hesitant at first to give information but after some reassurance did provide some details. These outlets are listed as Shop 1 to 4.

At a later stage taste panels were organised using score sheets translated into a number of different languages.

DETAILED RESULTS

MARKET REPORT

A study of the domestic and overseas market for dried seafood was completed in the first 6 months of this project. This study has been updated and is titled **"Evaluation of the market for dried seafood 1993-96"**. It was produced as the first milestone report and was intended to identify suitable prospects for experimentation. This publication accompanies the final report as a separate item.

DRYING TRIALS

The drying experiments so far have involved a wide variety of species due to industry requests and supplies of product. Individual processors can sometimes obtain raw material at quite low prices, thus the cost of producing a dried product is less, making drying an option. In some cases, the processors were prepared to pay for the access to the Heat Pump Drier (HPD) at commercial rates to produce a particular product. As this project is an industry oriented one some initial trials have been carried out for the benefit of those processors wishing to become established in the dried seafood market.

FISH AND FISH VISCERA

PILCHARDS

Pilchards from Western Australia were dried at two temperatures, 35°C and 45°C overnight. The temperature profiles of the pilchards during drying at the lower temperature and the load cell and humidity recordings are shown in Figures 1.1, 1.2 and 1.3 in Appendix 1. Table 1 shows the effect of drying pilchards.

Table 1. Weight reduction for pilchards from batch 1 for the first drying period at 35°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	467	200	42.8
Row 2	503	222	44.1
Row 3	560	234	41.8
Row 4	511	214	41.9
Row 5	686	274	40
Tray A	1245	548	44
Tray B	1331	555	41.7
Tray C	1435	640	44.6
Tray D	1196	507	42.4

Samples were stored in sealed bags with their position identified and some were removed and tested for moisture content and water activity. There was evidence of some case hardening as the moisture was still 36.7% and a second drying was required. This was carried out after an equilibration period of 7 days at 1°C. At the start of drying at 35°C the average moisture was 41.7%. Table 2 demonstrates the weight changes that occurred.

Table 2. Weight reduction for pilchards from batch 1 for the second drying period at 45°C.

Row number	Starting weight (g)	Final weight (g)	Proportion of starting weight %	Proportion of original weight %
Row 1	200	166	83	35.6
Row 2	224	182	81.3	36.2
Row 3	235	194	82.6	34.6
Row 4	223	182	81.6	35.6
Row 5	275	226	82.2	33
Tray A	549	457	83.2	36.7
Tray B	555	462	83.2	34.7
Tray C	534	641	83.3	37.2
Tray D	533	444	83.3	37.1
Tray E	497	414	83.3	32.8

Samples were stored in sealed bags with their position identified and some were removed and tested. As before there was still excessive moisture present. The next drying was conducted at 45°C. The temperature profiles are present in Appendix 1 as Figure 1.4. The moisture content after refrigerated storage and before drying was 35.4%. The identification positions from the first drying were retained for the second drying of the samples. The drying reduced this to 31.3%. Weight changes for each load cell screen are shown in Table 3.

Table 3. Weight reduction for pilchards from batch 2 for the first drying period at 45°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	520	205	39.4
Row 2	613	239	39
Row 3	508	183	36
Row 4	617	222	36
Row 5	537	198	36.9
Tray A	1101	405	36.8
Tray B	1115	401	36
Tray C	1295	518	40
Tray D	1152	410	35.6
Tray E	1286	471	36.6
Tray F	341	135	39.6

There was also evidence of some case hardening after drying at the higher temperature and a second drying at 35°C after 7 days refrigerated storage was conducted. The moisture before redrying was 35.4%. The identification numbers from the first drying were retained. As the first batch of pilchards was present at the same time as this batch the load cells could not be used for both sets of samples. Table 4 demonstrates the weight changes that occurred. Final moisture content ranged from 1.8% to 30.7%

Table 4. Weight reduction for pilchards from batch 2 for the second drying period at 45°C.

Row number	Starting weight (g)	Final weight (g)	Proportion of starting weight %	Proportion of original weight %
Row 1	205	171	83.4	32.9
Row 2	239	199	83.3	32.5
Row 3	181	155	85.6	30.5
Row 4	223	191	85.7	31
Row 5	199	169	84.9	31.5
Tray A	415	351	84.6	31.9
Tray B	407	346	85	31
Tray D	423	356	87.5	30.9
Tray E	485	408	83.3	31.7

As these samples were frozen it would not have been possible to attempt a cooked trial due to the fragile nature of the tissue..

ANCHOVIES

The Australian anchovy is very similar to the species sold in Asian markets. Samples from Western Australia, were loaded onto the HPD either raw (rows) or after cooking in 3% brine for three minutes (Tray) and dried at 35°C. The temperatures during drying are presented in Appendix 1, Figure 2.1. The weight reductions that occurred from drying are shown in Table 5. Due to instrument failure no measurements for humidity and load cell sensors were recorded.

Table 5. Weight reduction for anchovy dried at 35°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight %
Row 1	374	84	22.5
Row 2	318	72	22.6
Row 3	320	74	23.1
Tray 1	718	190	26.5

After drying, the moisture content of the raw fish was 11.2% and the water activity was 0.518 while the cooked fish had a moisture content of 7.1% and a water activity of 0.296. The appearance of the cooked anchovy was poor before drying with pieces missing and after drying this damage was even more noticeable.

WHITE SARDINE

A sample of anchovies of the Dove brand produced by Koluthara Exports was identified as the white sardine or herring, possibly *Kowala coval*. These are small deep bodied fish 5 to 10cm in length. The block of frozen fish weighing 974.4 was thawed to give 899.8g, a reduction to 92.3%. The initial moisture content was 78.1% . After drying at 55°C overnight this moisture level was reduced to 7.2% while the water activity was 0.302. Figure 2.2 in Appendix 1 shows the temperatures during drying. The weights obtained after drying are shown in Table 6.

Table 6. Weight reduction for white sardine dried at 55°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	524	133	25.4
Row 2	331	83	25.1

The sardines had dried adequately to a shelf stable product after 16 hours.

WHITE BAIT

A type of white bait available from Indonesia was presented for drying by an industry associate. This species was labelled as Chirimen. The fish were quite small and were dried at 35°C. There was difficulty spreading such small fish evenly without overlapping as they were so soft. The moisture after drying was 10.4% and the water activity was 0.57. Figure 3.1, in Appendix 1, shows the temperatures during drying. The weight changes are present in the following table.

Table 7. Weight reduction for white bait dried at 35°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	360	71	19.7
Row 2	374	70	18.7
Row 3	565	119	20.2
Row 4	435	82	18.9

AUSTRALIAN SALMON

Australian salmon can be obtained at very low prices so a drying trial of this species was carried out to provide some information about the conditions required for large fish. The fish were gutted and butterflied with the backbone removed. One fish per load cell screen was dried at 35°C. Figures 4.1, 4.2 and 4.3 display the temperatures, weight changes and humidity during drying. The following table contains the weight changes measured.

Table 8. Weight reduction for Australian salmon dried at 35°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	2977	2024	68
Row 2	2695	1831	68
Row 3	2612	1756	67

There was extensive case hardening requiring some equilibration time. After lengthy refrigerated storage another drying was carried out. The fish were dried for over 17 hours at 45°C. Figures 4.4, 4.5 and 4.6 display the temperatures, weight changes and humidity during drying. The weights, moisture content and the water activity of the flesh, after the second drying, are present in Table 9.

Table 9. Weight reduction for second drying of Australian salmon at 45°C.

Row number	Starting weight (g)	Final weight (g)	Proportion of starting weight (%)	Proportion of original weight (%)	Moisture content (%)	Water activity
Row 1	2028	1854	91.4	62	59.1	0.97
Row 2	1842	1711	92.9	63	60.2	0.96
Row 3	1767	1612	91.2	61	57.5	0.97

The rate of drying slowed after the first few hours then remained constant for the remaining time. There were residues of oil developing on the surface of the flesh and a slight lactic acid smell. The latter is not unexpected as the quality of the material at the start of the trial was poor. Because of the size of the individual fish further drying may be required for long term storage. The appearance, at this stage however, is suitable for the Asian market as whole fish are sold with high moisture content.

SPLIT MULLET

Sea mullet that had their roe and gizzards removed were split along the ventral surface and the bones removed. The average weight of fish for this treatment was 190g. The spread bodies were then salted overnight using dry salt. The fish were placed in the heat pump drier, four fish per tray and dried overnight at 50°C. The graph in Figures 5.1 displays the temperatures within individual fish during drying. At the end of the drying period the fish were removed, weighed and stored at 2°C. Some thicker sections of the muscle were still moist. The graph in Figure 5.2 displays the weight recordings from the load cells during drying while Figure 5.3 shows the humidity. Table 10 shows the weight reduction per tray.

Table 10. Weight reduction for mullet dried at 50°C.

Row Number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
1	772	439	56.9
2	819	461	56.3
3	779	424	54.4
4	768	405	52.7
5	641	332	51.8

Samples were taken to Hong Kong and Taiwan for appraisal. The feedback was that while they were well dried there was no market for dried mullet. This species is regarded as only useful for the roe and gizzard in Asia.

FISH MAW

This is one of the products identified as having good potential for Australian production. At present very few swim bladders from Australian caught fish are retained. Those that are kept for sale are frozen and exported in that form. One popular source of swim bladder in Asia is from the Nile Perch of Africa particularly the Lake Victoria area where large fish can be harvested. The barramundi is a close relative and although smaller in size can occasionally be caught in sizes of 30 kilograms or greater which are favoured for yielding the premium grade fish maw.

Swim bladders for these experiments were obtained from two sources. The first supply of reasonably priced cleaned barramundi swim bladders was produced in Myanmar (Burma). Another, purchased from Australian Pacific Seafood for $9/kg, contained varying sized cleaned maw, also from barramundi. As the swim bladder resides in the visceral cavity there is potential for microbial contamination during removal. To ensure a safe food product chemical treatment before drying is necessary.

Maw dried at 35°C

Domestic maw

Approximately 2kg of barramundi swim bladders obtained from Australian Pacific Seafood were thawed for drying. They were of varying sizes, mainly medium to small with a couple of large ones placed on the top to make the average size appear larger. They appeared quite clean but the bacterial load was high at 5.6 x 10^6cfu/g. The maws were dried at 35°C. Only one hours temperatures during drying were recorded by the datalogger due to a memory fault. This and the weight changes and humidity during drying can be observed in Appendix 1 as Figures 6.1, 6.2 and 6.3. Table 12 contains the weights before and after drying. Small sized maws were placed on the load cell rows while the medium sized maws were dried on the trays.

Table12. Weight reduction for fish maw dried at 35°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 2	225	77	34.2
Row 3	176	71	40.3
Tray 1	522	226	43.3
Tray 2	414	189	45.7

The colour of the maw was light, and because of the size, the small maw were adequately dried after 6 hours with a moisture of 12.1% and water activity of 0.363 while the bacterial count had reduced to 4.2 x 10^5cfu/g. The medium size maw, which had higher moisture content (23.7%) and water activity (0.839), also had a higher bacterial load (1.1 x 10^6cfu/g) and needed further drying. The bacterial levels before and after drying need to be reduced before an Australian export product can be produced.

Processing of fish maw prior to drying

The high bacterial counts on the maw are the main impediment to producing dried fish maw. The raw material originates in the gut cavity and becomes contaminated during removal. Thought of as a waste product by many fishermen, the handling of the maw is often inappropriate with the maw being left unwashed on deck for some time. The act of drying the maw encourages the growth of bacteria because of the elevated temperatures over long periods of time.

Heat treatment

While chemical treatment can be an option the application of heat to reduce the bacterial load of the maw was investigated. The first trial of this nature involved dipping of cleaned split domestic barramundi maw into boiling water. The maw were dipped into the boiling water and removed immediately or kept in the water for 5 or 30 seconds. As soon as the maw came in contact with the water they started to curl around the edges and this became more extensive as the time in the water increased. The edges also lost their normal silvery white appearance and became transparent. The surface also became sticky. The collagen was obviously being degraded to gelatine. The changes to the bacterial load are presented in Table 13.

Table 13. The effect on total plate count of fish maw being dipped in boiling water.

Cooking time (s)	Standard plate count (cfu/g)
0	3.6×10^4
1	2.4×10^3
5	0
30	0

More than one second in boiling water was required to remove all bacteria. This treatment had a profound impact on the dried product with the colour becoming quite dark and the curling was still present. There are no figures for temperatures, weight changes or humidity are present. Table 14 shows the recovery from each stage of this trial.

Table 14. Weight reduction for fish maw dipped in boiling water and dried at 35°C.

Cooking time (s)	Cleaned recovery (%)	Cooked recovery (%)	Dried recovery (%)
1	91.6	105.6	36.5
5	101.1	120.2	40.8
30	93.3	105.6	35.0

The next trial involved exposing the maw to lower temperatures. A water bath was used to heat water to 80°C and 70°C. The maw were then dipped in the water for different times. The moisture of the cleaned maw was 67.1% and the bacterial count was 6.7×10^4cfu/g. The maw became sticky after heating and were difficult to separate. The average weight of the maw before drying was 150g. The colour of the dried maw became slightly darker and the curling was more apparent as the amount of heating increased. The changes after treatment are shown in Table 15.

Table 15. The effect on the moisture content and bacterial count of fish maw being dipped in heated water.

Measured Parameter	Heat Treatment			
	1s at 80°C	5s at 80°C	15s at 80°C	1s in 70°C
Cooked moisture (%)	71.4	68.9	70.0	70.1
Cooked plate count (cfu/g)	8.1×10^4	1.0×10^3	2.0×10^2	1.3×10^4
Cooked recovery (%)	106.4	105.9	105.0	104.5
Dried moisture (%)	17.9	17.5	16.0	20.8
Dried water activity	0.616	0.625	0.651	0.719
Dried plate count (cfu/g)	0	4×10^3	2.5×10^2	6.5×10^2
Dried recovery (%)	43.7	42.1	40.7	44.5

The maw were adequately dried by the end of the run. The physical changes to the maw were too extreme to permit the use of heat as a means of reducing the bacterial load on the raw material and suggests that chemical treatment is necessary. The following section details the various chemicals investigated.

Imported maw treated with chemicals

Sodium hypochlorite treated maw dried at 45°C

Imported swim bladders from barramundi were prepared by splitting and then washing in water or soaking in a 2% sodium hypochlorite solution overnight. A variety of sizes was available but drying was restricted to the largest as these to attain the best prices. The operating temperature for the HPD was 45°C.

There were some small spots present which appeared to be oil and some remaining moisture. Samples were sent to buyers overseas for appraisal. The main comment obtained was that while the colour and aroma were good the maws were not very thick. A further treatment given to some maws was an overnight soak in a hydrogen peroxide solution. This improved the thickness of the product. There was a slight thickening but the colour changed to a silvery white, unlike any product offered commercially. The graphs in Figures 6.4, 6.5 and 6.6 show the temperatures, weights and humidity during drying. The weights of individual rows are presented in Table 16.

Table 16. Weight reduction for fish maw dried at 45°C.

Row number	Treatment	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	no chlorine	725	177	24.2
Row 2	chlorine dip	523	170	31.7
Row 3	chlorine dip	231	73	31.6

The chemically treated and dried maws had a final moisture of 8.4% and water activity of 0.242.

Domestic maw treated with chemicals

Stocks of maw were sourced from a barramundi fisher in Karumba. The latter were handled poorly, exhibiting knife cuts, staining and enzymic damage from delayed freezing, and still retained connective and adipose tissue. These maw were not slit open and as the bulk of Asian product is sold uncut the next drying trials were of intact tubes. At $3.50/kg this was a more expensive product than the imported one considering further cleaning was required. More recent prices for large maw from black jew and barramundi (500g) have been between $12 and $15/kg. To improve the quality of raw material some training of fishers may be required and once demand from industry increases pricing can be increased to provide incentive for better handling. The former product was used in the initial trial. All other trials utilised domestic product. The domestic produced barramundi maws were analysed prior to processing. The moisture content was 70.11%, the water activity 0.99, the pH 6.8 and lipid content 2.9%.

H_2O_2 treatment

A bleaching stage, such as that used during processing shark fin, of a 3% hydrogen peroxide dip for several hours was trialed next. The imported maw always produced a superior product because of better handling at the time of capture. Better handled samples had been requested of suppliers at Kurumba and another contact in Darwin had also been asked to send samples. A Brisbane company currently producing meat jerky has stated that it is eager to continue with this product into commercialisation trials.

Domestic barramundi maw were cleaned of excess tissue and divided into two batches but were not cut open. One batch was placed in a 2% solution of H_2O_2 for 2 hours at room temperature while a control set was kept untreated. The maws were then held at 3°C overnight before initially drying at 55°C. The maw were of mixed size and the average weight before drying was 50g for small, 150g for medium and 350g for large maw. Prior to drying the H_2O_2 treated maw exhibited a puffed appearance, one floating right on the top of the solution and there was a silvery look to the outer surface. The graphs in Figures 6.7, 6.8 and 6.9 show the temperatures, weights and humidity during drying. Table 17 shows the recovery from each processing stage as a proportion of the original weight.

Table 17. Weight recovery for H_2O_2 treated and untreated barramundi maws.

Treatment	cleaned recovery (%)	drained recovery (%)	Row number	Size and number	wet weight (g)	dried weight (g)	Proportion of wet weight (%)
H_2O_2	99.0	96.7	Row 1	large (2)	676	381	56.4
H_2O_2	99.0	96.7	Row 2	medium (2)	296	143	48.3
H_2O_2	99.0	96.7	Row 3	small (8)	515	222	43.1
no chemicals	99.5	96.7	Tray 1	medium (13)	679	294	43.3
no chemicals	99.5	96.7	Tray 2	medium (13)	654	284	43.4
no chemicals	99.5	96.7	Tray 3	medium (11)	567	243	42.9

The maws required a second drying after some equilibration. This was carried out at 35°C. Table 18 gives the weight recoveries for the second drying.

Table 18. Weight recovery for H_2O_2 treated and untreated barramundi maws after second drying.

Treatment	Row number	Size and number	weight after equilibration (g)	weight after second drying (g)	Proportion of original wet weight (%)
H_2O_2	Row 1	large (2)	383	237	34.9
H_2O_2	Row 2	medium (2)	143	116	39.2
H_2O_2	Row 3	small (8)	197	172	37.6
no chemicals	Tray 1	medium (13)	293	254	37.5
no chemicals	Tray 2	medium (13)	282	247	38.0
no chemicals	Tray 3	medium (11)	212	185	37.4

The pH, moisture, water activity and bacterial load of the maw before and after drying are present in Table 19.

Table 19. Physical and microbiological characteristics of chemically processed fish maw with processing before and after drying.

Treatment	pH	Moisture (%)	Water activity	Standard plate count (cfu/g)
No chemicals	6.8	64.1	0.980	1.8×10^5
H_2O_2 treated	7.2	68.3	0.983	4.1×10^3
No chemicals, 1st dry, small maw	-	21.0	0.731	1.5×10^4
No chemicals, 1st dry, large maw	-	34.4	0.933	2.0×10^3
H_2O_2 treated, 1st dry small maw	-	21.8	0.791	5.8×10^4
H_2O_2 treated, 1st dry large maw	-	47.4	0.969	7.5×10^4
No chemicals, 2nd dry, small maw	6.81	11.6	0.316	2.4×10^3
No chemicals, 2nd dry, large maw	6.81	18.6	0.703	1.4×10^4
H_2O_2 treated, 2nd dry small maw	7.2	11.7	0.312	6.1×10^4
H_2O_2 treated, 2nd dry large maw	7.2	24.7	0.819	3.3×10^5

Figures 6.10, 6.11 and 6.12 in Appendix 1 show the temperatures, weight changes and humidity during the second drying. After drying some staining from blood was still evident but not as extreme as the control. The peroxide may have reduced the initial bacterial load but drying

encouraged growth so that by the end of the second drying the count was back to the starting level with little difference between this treatment and the chemically free samples. As both batches dried, fat was exuded. This dripped off one row or tray onto the one beneath. The dried pH did not change from the wet levels. Because of the surface area to volume ratio the large maw dried more efficiently than smaller ones.

Sodium hypochlorite treatment, dried at 55 °C

The first batch (11.052kg) of domestic swim bladders was thawed overnight (10.265kg), divided into two batches and cleaned of adhering tissue This required 3 hours of scrubbing and trimming to produce satisfactory material for drying. Large amounts of adipose tissue and connective tissue as well as blood vessels and clots adhered to the inner and outer surfaces of the maw. After cleaning the pH was 7.2, water activity 0.972, and standard plate count was 4.6 x 10^8cfu/g. Both were given a 2 hour dip in a sodium hypochlorite solution to reduce microbial growth (9.050kg). The moisture increased to 77.3%, the water activity increased slightly to 0.977, the pH increased to 7.63 and the plate count decreased significantly to 4.2 x 10^5cfu/g. One batch of maw was then dried over night at 55°C. The graphs in Figures 6.13, 6.14 and 6.15 show the temperatures, weight changes and humidity during drying. Table 20 contains the yield data.

Table 20. Weight reduction for fish maw dried at 55°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	1309	720	55.0
Row 2	1270	652	51.3
Row 3	1315	657	50.0
Row 4	1087	616	56.7

The characteristics of the dried maw after drying are present in Table 21.

Table 21. Moisture, water activity and microbial count of fish maw dried at 55°C.

Size	Moisture (%)	Water activity	Standard Plate Count (cfu/g)
small	18.95	0.704	7 x 10^5
large	28.82	0.910	3 x 10^5

There was not much change in the bacterial count after drying. Droplets of oil were present on the surface of the maw after drying, especially the large ones. These large maws also retained some moisture and required a second drying after some equilibration time. To reduce the mobilisation of oil and the water content further, the maws were redried, this time overnight at 35°C. The second drying was carried out in combination with another batch of maw so no weight figure was obtained. The graphs in Figures 6.16 and 6.17 show the temperatures and humidity during this drying. The yield data is presented in Table 22.

Table 22. Weight reduction for fish maw dried for a second time at 35°C.

Row number	Starting weight (g)	Final weight (g)	Proportion of starting weight (%)	Proportion of original weight (%)
Row 1	721	605	83.9	46.2
Row 2	613	508	82.9	42.5
Row 3	658	542	82.4	41.2
Row 4	615	507	82.4	46.7

The visual appearance of the maws was poor with oil induced staining present. The large maws at the end of the second drying had a moisture content of 30.2% and water activity of 0.897, a pH of 7.31 and a microbial count of 1.4 x 10^4cfu/g. This indicates that there is still excess water present in the product.

Sodium hypochlorite treatment, dried at 35°C

The next trial involved the use of a lower initial drying temperature of 35°C. The maw had been prepared using the same chlorine treatment as previously. It was noted that the number of large specimens present were less than for the previous batch. The graphs in Figures 6.18, 6.19 and 6.20 show the temperatures, weights and humidity during drying. The yield data is shown in Table 23.

Table 23. Weight reduction for fish maw dried at 35°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	1301	553	42.5
Row 2	1050	524	50.0
Row 3	1286	728	56.6
Row 4	432	179	41.4

The moisture and water activities of the large pieces were 32.6% and 0.917 and the pH was 6.95. The microbial count was 2.2 x 10^8cfu/g. These results indicate that further drying is required for some maw. This was carried out in conjunction with a second drying of maw exposed to an initial higher temperature. The graphs in Figures 6.21, 6.22 and 6.23 show the temperatures, weights and humidity during the second drying at 35°C. The yield data is shown in Table 24.

Table 24. Weight reduction for fish maw dried for a second time at 35°C.

Row number	Starting weight (g)	Final weight (g)	Proportion of starting weight (%)	Proportion of original weight (%)
Row 1	555	461	83.1	35.3
Row 2	526	437	83.1	41.6
Row 3	688	559	81.3	46.0
Row 4	171	152	88.9	36.8

The characteristics of the dried maw are presented in Table 25.

Table 25. Moisture, water activity and microbial count of fish maw dried at 35°C.

Size	Moisture (%)	Water activity	Standard Plate Count (cfu/g)
small	23.1	0.782	1.3 x 10^6
large	41.1	0.963	6.4 x 10^6

The high bacterial count indicates that pretreatment is necessary to produce a safe product. The amount of discolouration that occurs at higher temperatures indicates that 35°C is the optimum for fish maw. The density of the large maw encourages case hardening. For efficiency at least two or more separate drying runs are required with some moisture equilibration needed after each session in the heat pump drier.

Sodium hydroxide and sodium hypochlorite treatment

As the earlier methods applied were not very effective, a series of other treatments were trialed to reduce the initial bacterial load of fish maw. The poor quality material which had a high bacterial count was again used to determine efficacy. Excess exterior tissue and fat deposits were removed manually. This was best achieved using a level edged knife which was scrapped over the exterior surface. Care was taken to keep the blade vertical so no cuts developed. The maw were cut open along one side using a set of bone cutting scissors, similar to those used to prepare chichen pieces, to remove the lining of blood vessels. This tissue was removed using a nylon scrubbing brush. Care should be taken to remove all the lining tissue revealing the silvery surface of the collagen. The maw were then well washed before treatment.

To try to reduce the lipid content an overnight soaking of 10.99kg of maw in a 0.1N NaOH solution held at 5°C was carried out. After this the maw were washed in clean freshwater then kept overnight in a sodium hypochlorite solution at 5°C to reduce the bacterial load and provide some bleaching. A control batch was cleaned manually then placed in the sodium hypochlorite solution at the same time. The next day the maw were drained of excess sodium hypochlorite solution then washed for one hour in freshwater.

A total of 3.41kg manually cleaned maw and 11.25kg of NaOH treated maw were ready for drying in the HPD at 35°C. Some maw had plastic mesh inserted keeping the end of the tube open to enhance drying. The NaOH treated maws dried at the same time were placed on trays while the manually cleaned maws (controls) were placed on the load cell rows. The graphs in Figures 6.24, 6.25 and 6.26 show the temperatures for both treatments, weight changes of sodium hypochlorite only treated maw and humidity for both treatments during drying. Drying recoveries are shown in Table 26.

Table 26. Weight reduction for fish maw dried at 35°C.

Row number	Starting weight (g)	Dried weight (g)	Proportion of starting weight (%)
Row 1	919	372	40.5
Row 2	724	276	38.1
Row 3	774	300	38.8
Row 4	530	166	31.3
Row 5	517	161	31.1
Tray 1	2157	485	22.5
Tray 2	2300	446	19.4
Tray 3	2137	350	16.4
Tray 4	1828	281	15.4
Tray 5	2173	310	14.3

The changes in the physical and microbiological parameters of the maw for the various treatments are shown in Table 27.

Table 27. Physical and microbiological characteristics of fish maw with processing and drying.

Treatment	pH	Moisture (%)	Water activity	Standard Plate Count (cfu/g)
Thawed	7.2	70.1	0.994	2.2×10^8
Manual clean, chlorine dipped	7.6	77.3	0.977	1.5×10^7
Cleaned, NaOH then chlorine dipped	9.05	-	-	not detected
Manual clean, chlorine dipped, dried	8.5-9.4	11.8	0.315	1.1×10^8
Cleaned, NaOH then chlorine dipped, dried	9.7	53.2	0.979	not detected

The pH increases when fish maw are dried. Chlorine treatment does reduce the bacterial load of fish maw by one log factor. When the maw is dried the favourable conditions encourages growth and the amount of bacteria returns to the original level before chlorine treatment. This level is too high to meet export standards. The NaOH treatment was not effective in removing all of the fat present on the surface of the maws. Manual cleaning resulted in a better appearance.

There was no major effect on the microbiological condition of the manually cleaned and chlorine dipped fish maw. The combination of sodium hydroxide and sodium hypochlorite was successful in reducing the microbiological load to an undetectable level. Unfortunately this treatment also had some effect on the appearance of the maw resulting in a grey to green colouration, the retention of higher amounts of moisture and a surface feel of oiliness. There was an odour of ammonia present on thawing the fish maw. This was probably due to the poor treatment prior to freezing. Enzymic damage was evident with the maws tearing easily during cleaning. The difficulty in removing fatty tissue and blood vessels inside and outside the maws after thawing indicates they should be cleaned effectively before any freezing is carried out.

Sodium hydroxide treatment

Previous experiments with this chemical resulted in major reductions in bacterial load but also changes in appearance and pH of the dried product. A solution of 0.1N NaOH was used to dip pieces of barramundi maw for much shorter times and were followed by a 30 minute rinse in fresh tap water. As fish maw is a dense tissue which is difficult to insert a stab electrode into, the pH was determined by preparing a homogenised solution containing 10g of maw with 100mL of distilled water. The thawed material had a pH of 6.05 and after cleaning a pH 6.0. Table 28 shows the pH of maw exposed to a series of times in NaOH and changes of fresh water.

Table 28. pH of fish maw dipped in 0.1N NaOH and rinsed in fresh water.

Time in NaOH (minutes)	Number of rinses in fresh tap water 1	2	3	4
15	9.5	9.22	9.85	9.6
30	10.0	10.0	9.85	9.75
60	10.0	10.0	10.0	10.0

The high pH obtained would lead to flavour problems in the dried product so even shorter dipping times were trialed. The rinse time was also reduced to 15 minutes. The best treatment would be one that does not lead to a high pH but does reduce the bacterial load. The unclean maw had a total plate count of 9.5 x 10^3cfu/g. The pH of the cleaned barramundi maw was 6.99. As the shorter times would be less effective in reducing bacterial loads total plate counts were also measured. Table 29 gives the pH and bacterial counts for these maw.

Table 29. pH and total plate count of fish maw dipped in 0.1N NaOH and rinsed in fresh tap water.

Time in NaOH (minutes)	Number of rinses in fresh tap water	pH	Standard Plate Count (cfu/g)
0	0	6.99	3.2×10^4
1	1	7.55	1.3×10^5
1	2	7.85	8.4×10^3
1	3	7.5	1.3×10^4
1	4	8.06	3.3×10^3
2	1	8.7	1.1×10^4
2	2	8.4	7.2×10^4
2	3	7.89	1.8×10^5
2	4	8.68	1.2×10^4
5	1	8.61	-
5	2	8.53	-
5	3	8.49	-
5	4	9.2	4.2×10^3

The cleaned only maw had quite low bacterial counts this time so it was difficult to exhibit the benefits of sodium hydroxide treatment. It was effective after longer dipping times. The one minute dip had the least impact on pH and led to similar bacterial counts as those observed with the longer dipping times. This dip time in NaOH was used on a batch of maw prior to drying. Two sizes of maw were used. Maw of a length between 20 and 27cm and width between 5 and 8cm were designated large while those with lengths between 13 and 20cm and widths between 3 and 5cm were called small. The maw were split and cleaned, dipped for 1 minute in 0.1N NaOH and rinsed for 30 minutes in running tap water. The bacterial count of the cleaned maw (1.5×10^5cfu/g) was reduced to 1.8×10^3cfu/g. The pH however increased from 6.85 to 10.18. The settings used for the heat pump drier were intermittent (2hr on/ 2hr off) drying at 35°C. The large maw were placed on the load cell rows and the small maw on stainless steel mesh trays. Table 30 shows the weight changes due to drying.

Table 30. Weight reduction for fish maw treated with 0.1N NaOH for 1 minute and dried intermittently at 35°C.

Row number	Starting weight (g)	Dried weight (g)	Proportion of starting weight (%)
Row 1	727	274	37.7
Row 2	526	177	38.1
Row 3	487	153	31.4
Row 4	95	30	31.6
Tray 1	867	361	41.6
Tray 2	441	117	26.5

There were white patches which remained present in the dried product. The graphs of the temperatures, weight changes and humidity during drying are present in Appendix 1 as Figures 6.27, 6.28 and 6.29. The high pH with even this short dip time indicates that some pH adjustment is needed prior to drying. There was no apparent improvement by using intermittent drying for fish maw.

Sodium hydroxide and sodium metabisulphite treatment

The sodium hydroxide treatment described above was tried in combination with a sodium metabisulphite ($Na_2S_2O_5$) dip to investigate the reduction of high pH in the dried maw. The maws were cleaned, dipped in 0.1N NaOH for one minute and then rinsed in tap water for 10 minutes. The maws were then dipped in a concentration of 1% $Na_2S_2O_5$ for 1, 2 or 5 minutes and given another rinse. Table 31 lists the changes to the maws before drying.

Table 31. pH and microbial count of fish maw after treatment with sodium hydroxide and sodium metabisulphite.

Treatment	pH	Standard plate count (cfu/g)
Cleaned only	6.98	6.7×10^4
NaOH and 1 min $Na_2S_2O_5$	7.72	1.5×10^3
NaOH and 2 min $Na_2S_2O_5$	7.25	3.5×10^3
NaOH and 5 min $Na_2S_2O_5$	7.10	2.5×10^3

The sodium hydroxide treatment reduced the bacterial count by one log phase. The sodium metabisulphite did not appear to contribute to any further reductions in the wet maws but did counter the sodium hydroxides effect on the pH. As the dip time increased the pH dropped. The pH of the maw dipped for 1 minute was still elevated and would increase greatly after drying so only the maw dipped for 2 and 5 minutes were dried. The average weight of the maw before drying was 100g. The graphs of the temperatures, weight changes and humidity during drying are present in Appendix 1 as Figures 6.30, 6.31 and 6.32. The recoveries, pH and bacterial counts for the dried maw are presented in Table 32.

Table 32. Weight recovery, pH, microbial count and sulphite residue of dried fish maw treated with sodium hydroxide and sodium metabisulphite.

Treatment	Dried recovery (%)	pH	Moisture (%)	Water activity	Standard Plate Count (cfu/g)	SO_2 residue (mg/kg)
Cleaned only	30.3	6.67	11.2	0.352	5.0×10^3	-
2 min $Na_2S_2O_5$	33.6	7.06	11.0	0.408	7.0×10^2	830
5 min $Na_2S_2O_5$	36.5	6.93	12.7	0.406	1.0×10^2	1505

The sodium metabisulphite was effective in returning the pH to the pretreatment level for both dip times. There was also a reduction in the bacterial load after drying which could have been assisted by the sulphite residue as treatment with sodium hydroxide alone. Sulphite does have some bactericidal properties and the high level of residue in the dry product would certainly been beneficial. These residues are high and can be considered unsuitable for production of dried fish maw.

Potassium sorbate treatment

Potassium sorbate has been used to inhibit growth of microorganisms in seafood and other food products by many researchers. While it is more effective at a pH below 6 it is still has some effective action at 7. The first application of this chemical involved dipping the cleaned maw in a 5% solution for 1, 2 or 5 minutes followed by a 5 minute rinse in running water. The pH and microbial count were recorded and are presented in Table 33. No drying of these maw was attempted.

Table 33. pH and microbial load of fish maw dipped in 5% potassium sorbate.

Dip time (min)	pH	Standard plate count (cfu/g)
0	6.43	3.2×10^4
1	6.54	1.6×10^4
2	6.47	1.5×10^4
5	6.7	1.3×10^4

There was only a slight reduction in the microbial count. There was some selective action by the sorbate as the dip removed some types of bacteria which developed yellow colonies when grown on plate count agar. As this chemical is used as an additive the short dipping times used here may not have been sufficient to cause major reductions in microbial population.

The next trials incorporated longer exposures. The maw were cleaned manually and dipped in 5% potassium sorbate for 5, 10 or 15 minutes and then rinsed for 5 minutes in running water. Another treatment was to dip for 5 minutes and then dry without any rinsing. The maw were not large and ranged from 40 to 60g each. The maws were then dried at 35°C. Figures 6.33, 6.34 and 6.35 in Appendix 1 show the temperatures, weight changes and humidity during drying. Table 34 shows the microbial counts present before and after drying.

Table 34. The microbial load of fish maw dipped in 5% potassium sorbate.

Dip time (min)	Wet standard plate count (cfu/g)	Dry standard plate count (cfu/g)
0	1.1×10^6	7.0×10^4
5	4.0×10^5	3.4×10^4
5, no rinse	1.4×10^6	2.8×10^4
10	5.5×10^5	8.5×10^4
15	1.2×10^6	4.8×10^4

There were no major improvements in bacterial count after using potassium sorbate. The maw dipped but not rinsed had the lowest count but this was only half of the control level and not the log reduction that is normally required for bacterial control. The physical condition of the dried maw are presented in Table 35.

Table 35. Weight recovery, pH, moisture and water activity of dried fish maw treated with sodium hydroxide and sodium metabisulphite.

Dip time (min)	Dried recovery (%)	pH	Moisture (%)	Water activity
0	37.6		13.3	0.447
5	34.6		13.4	0.506
5, no rinse	37.7		15.2	0.46
10	32.8		13.6	0.465
15	35.5		14.2	0.47

Product evaluation

Samples of dried maw from earlier trials were presented to staff of Chinese grocery stores in Brisbane for their appraisal. It was hoped that the information obtained would lead to better processing methods being developed. A wholesale price for these samples was also requested.

Retail prices in Brisbane have been $159/kg for broken pieces, $250/kg whole for small maws and $1.10/60g cooked.

Shop No. 1
No information was available on this type of product at the first shop approached for product evaluation as it was not sold by this particular outlet.

Shop No. 2
The original sex of the fish from which the maw originated was of some importance to the traditional retailer buyer relationship. No price difference appeared to be prevalent between male and female derived fish maw. The colour and texture of the heat pump dried maws was considered correct for the product. As with other samples it was considered that heat pump product lacked the necessary aroma. The size of the fish maw appeared to be an important issue for the retailer, with a premium priced awarded to the thicker and larger maws. The largest heat pump dried sample was considered larger enough but not thick enough to command the premium price. As an example of wholesale purchase price the larger heat pump sample would be valued at least AUD$50 per kg. The smaller maws which were roughly half the size of the large sample would command a wholesale price of approximately AUD$17 per kg. The market for dried fish maw was not considered as large as the market for dried prawns. The cooked ready to eat final product should be both thick and soft in nature.

Shop No. 3
The colour of the heat pump dried sample appeared acceptable though they were lacking in size and thickness. No price or value was ventured for the product.

Shop No. 4
Information provided by the assistant at this outlet was that dried fish maws were specific to the Cantonese and Vietnamese diet and as such had more regional than overall appeal by traditional dried seafood consumers. The heat pump dried samples were perceived as very high quality for colour, cleanliness and presentation. This contrasted with the retail product which varied greatly in colour and had areas of dried fatty deposits. The heat pump dried sample was considered superior to their current retail lines. The issue of aroma which is associated with most other dried seafood products was not as important a factor with dried fish maw. The large heat pump dried sample was equivalent in size to the largest fish maw on sale in this establishment and these were sold in weights of 100 grams to 650 grams. The large dried fish maw retailed for A$112 per kg and it was suggested that the heat pump samples could command a better price. Smaller product on sale appeared to be cooked in oil and sold in sizes ranging from 20 grams to 100 grams. Small cooked fish maws retailed for A$21.50 per 100 grams. As a final comment the shop assistant stated that retail customers prefer large fish maw while the restaurant trade prefers smaller maws. This comment has implications for the viability and distribution of both large and small dried fish maw.

Jew fish maw
As the process for fish maw had been investigated in detail a final batch was prepared for use in a cunsumer based taste panel. A new source in Darwin was found and it supplied good sized clean swim bladders from the black jew *Protonibea diacanthus*. The maw was shipped frozen in shatter pack and cost $12 per kilogram. The maw were thawed by water immersion, split upon using bone cutters, manually cleaned and then rinsed in running water. The recovery from cleaning was 82.6%. The cleaned maw were dried at 35°C overnight. Figures 6.36, 6.37 and 6.38 in Appendix 1 show the temperatures, weight changes and humidity during drying. Table 36 shows the weights of fish maw before and after drying and the recovery for each row or tray.

Table 36. Weight recovery of dried jew fish maw.

Row and tray number	Wet weight (g)	Number of maw present	Dried weight (g)	Dried recovery (%)
1	583	4	228	39.1
2	757	3	323	42.7
3	404	3	158	39.1
4	516	2	218	42.3
5	461	2	199	43.2
XL	654	4	259	39.6
T8	776	4	318	41.0
T3	703	4	287	40.8
XH	822	4	336	40.9
XB	859	4	357	41.6
1	822	4	340	41.4

Some of the larger maw had small patches of moisture trapped within the thickest parts requiring some equilibration and further drying. Table 37 gives the weight changes for a second drying after an equilibration of one week at 2°C.

Table 37. Weight recovery of second driying of jew fish maw.

Row number	1st Dried weight (g)	Number of maw present	2nd Dried weight (g)	Dried recovery (%)
1	288	3	265	92.0
2	275	3	251	91.3
3	98	1	91	92.9
4	219	2	206	94.1
5	81	1	78	96.3

The final recovery from drying 7.44kg of cleaned jew fish maw is 39.7%. When the losses due to cleaning are combined with the drying recovery then an overall recovery from frozen raw material to dried maw is 32.8%. Figures 6.39, 6.40 and 6.41 in Appendix 1 show the temperatures, weight changes and humidity during the second drying. Table 38 shows the microbial counts present before and after drying.

Table 38. The microbial load, pH, moisture and water activity of dried fish maw.

Stage	Microbial load (cfu/g)	pH	Moisture (%)	Water activity
Thawed	1.4×10^5		65.2	0.979
Cleaned	1.1×10^4		63.4	0.989
Dried	5.0×10^2	6.19	14.6	0.494
Samples equilibrated and dried 2nd time	1.1×10^4	6.26	13.8	0.424

These samples were presented to a number of regular consumers of fish maw for evaluation.

Taste pannel report

To date:

- Questionnaires and cover sheets have been designed and translated into both Cantonese and Vietnamese.
- These have been distributed to English language colleges, DPI staff of Asian origin, several Asian grocery stores in Fortitude Valley, Sunnybank Plaza Shopping Centre in Brisbane and seafood driers based in Hong Kong.
- Response has not been prolific to date. Five questionnaires have been returned on the fish maw. There are five more questionnaires that were requested to be returned by the 20 th April, 1997.

- Further work will be done to endeavour to increase the numbers of participants.

Results of returned forms

Respondents were chosen on the basis of their familiarity with eating and cooking fish maw.

Uncooked maw

- The size was graded as the same or better
- The thickness was considered to be the same or better.
- The cleanliness was thought to be better or much better then the maw they usually bought.
- 80% of respondents thought the colour was better then the maw they usually bought.
- They all thought the feel of the maw was better and the smell was the same or better.

Cooked maw

- The responsents cooked the maw by deep frying or boiling.
- The cooked flavour was considered to be the "same as" the maw they usually bought.
- 80% of the respondents thought the texture of the maw was the same as they usually bought. One respondent thought the texture was better.

OVERALL, 80% CONSIDERED THE MAW TO BE BETTER THAN THAT WHICH THEY USUALLY BOUGHT.

Processing method for fish maw

Because the maw is in close association with the gut it should be removed as soon as possible after capture. If there is any delay in gutting the digestive enzymes will damage the tissue causing weakening and staining. Contamination with bacteria will also be worse in fish left ungutted. The maw should be cleaned of fat and other tissues adhering to the exterior surface. This operation can be easily be performed using a long flat knife held vertically and scrapped over the surface. If possible the inside should also be cleaned of blood and veins before freezing.

Dried fish maw is sold whole or split. If the product is to be dried whole, after the exterior has been effectively cleaned, the end where the ducts enter the bladder should be cut off and the bladder turned inside out. The best tool to use for cutting wet fish maw is a pair of poultry scissors. The lining of blood vessels can then be removed. Any delay in removing the maw after capture will result in tearing when the bladder is inverted. If the product is to be sold split open they should be cut open down the side using the poultry scissors. The blood vessels are then removed using a long flat knife held vertically and scrapping over the surface. A nylon brush can also be used to clean both surfaces without much damage. The maw are then ready to be placed in the heat pump drier. As they tend to curl up during drying they could be placed between a mesh frame to retain good shape.

Unlike other dried seafood it is important to remove as much moisture as possible from fish maw. Cleaned fish maw will have a moisture content between 65 and 70% and water activity between 0.995 and 0.98. As the main component is collagen drying should be carried out at the lowest temperatures possible (<40°C). Pasteuration treatment such as blanching is not suitable for use on fish maw. A 10 minute dip in 10% potassium sorbate can be used to give protection against bacterial growth during drying and subsequent storage. Small pieces measuring 13-20cm in length, 3-5cm in width and usually weighing 50g dry within 6-12 hours. Medium pieces of up to 150g take longer and large pieces 350g and bigger (length 20-27cm and width 5-8cm) have to be dried in two sessions of 12 hours because case hardening can develop. Drying for longer than 12 hours continually can result in irreversible case hardening. After the first drying the maw should be kept up to a week at <5°C to allow the trapped moisture to move towards the surface and equilibrate. A manual has been prepared for this product and accompanies the report.

SHARK

Fillets

One of the cooperating processors identified a market for dried shark fillets. These were becoming popular as a replacement in Latin American countries for dried salted Norwegian cod because of the limited supplies on offer. The specifications for the product were limited but it was decided to produce a range of samples for the buyer to appraise, with and without salt coating the cut surface. The first trial involved the drying of small shark fillets, up to 50cm in length, at 35°C for 24 hours. At the start of drying the moisture was 76.6% and the standard plate count was 4.9×10^5 cfu/g. The graphs in Figures 7.1, 7.2 and 7.3 show the temperatures, weights and humidity during drying at 35°C. Individual fillets were weighed before and after drying and the weight changes are present in Table 39.

Table 39. Weight reduction for shark fillets dried at 35°C.

Row number and fillet number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1.1	469.4	222	47.3
Row 1.2	569.9	294	51.6
Row 1.3	384.5	152	39.5
Row 2.1	482.4	231	47.9
Row 2.2	229.7	91	39.6
Row 2.3	101.9	25	24.5
Row 3.1	289.1	105	36.3
Row 3.2	533.1	229	43.0
Row 3.3	461.7	219	47.4
Row 4.1	423.5	199	47.0
Row 4.2	488.8	241	49.3
Row 5.1	305.0	105	34.4
Row 5.2	368.1	158	42.9

With a moisture of 48.5% and water activity of 0.931 there was still plenty of water present within the large fillets requiring further drying. Because of the favourable conditions the plate count increased to 1.6×10^7 cfu/g. The small fillets were more effectively dried and had a moisture of 12.63% and water activity of 0.56. The fillets were stored for several days at 1°C before a second drying at 35°C. At this time the microbial count was 1.1×10^5 cfu/g for a large fillet and 1.1×10^4

cfu/g for small fillets. The graphs in Figures 7.4, 7.5 and 7.6 show the temperatures, weights and humidity during the second drying at 35°C. Table 40 contains the yield data.

Table 40. Weight reduction for shark fillets dried at for a second time at 35°C.

Row number and fillet number	Starting weight (g)	Final weight (g)	Proportion of starting weight (%)	Proportion of original weight (%)
Row 1.1	222	167	75.2	35.6
Row 1.2	269	203	75.5	35.6
Row 1.3	151	110	72.9	28.6
Row 2.1	230	172	74.8	35.7
Row 2.2	91	68	74.7	29.6
Row 2.3	22	20	90.9	22.3
Row 3.1	104	78	75.0	27.0
Row 3.2	230	167	72.6	31.3
Row 3.3	218	163	74.8	35.3
Row 4.1	199	146	73.4	34.5
Row 4.2	242	181	74.8	29.9
Row 5.1	105	79	75.2	25.9
Row 5.2	157	117	74.5	31.8

At the end of the second drying the parameters for large and small fillets respectively were moisture 39.5% and 29.1%, water activity 0.891 and 0.814, and plate count 2.9 x 10^8 cfu/g and 2.3 x 10^8 cfu/g. The high level of bacterial contamination of the raw material indicates the need for a treatment stage before drying.

The salted shark had refined salt sprinkled over the upper surface making sure that no areas were left untreated. Each fillet received approximately 20g of salt and two fillets were placed on each row. The graphs in Figures 7.7, 7.8 and 7.9 show the temperatures, weights and humidity during drying at 35°C. Table 41 gives the yield data.

Table 41. Weight reduction for salted shark fillets dried at 35°C.

Row number	Wet weight (g)	Wet weight after salting (g)	Dried weight (g)	Proportion of original salted weight (%)
Row 1	766.4	806.7	395	49.0
Row 2	700.1	741.6	367	49.5
Row 3	784	828.4	436	52.6
Row 4	921.7	963.9	516	53.5
Row 5	691.9	722	357	49.5

There was an electrical fault with the heat pump drier during this first drying which reduced the exposure time to the drying conditions. There was still moisture present within the fillets which required further drying. The fillets were stored for several days at 1°C before a second drying at 35°C. Before this next drying the parameters for large and small fillets respectively were moisture 53.1% and 45.4%, water activity 0.899 and 0.755 and plate count 1.1 x 10^5 cfu/g and 1.1 x 10^4 cfu/g. Considering the amount of water available the salt was very effective in inhibiting bacterial activity. The graphs in Figures 7.10, 7.11 and 7.12 show the temperatures, weights and humidity during the second drying at 35°C. The weight changes are listed in Table 42.

Table 42. Weight reduction for salted shark fillets dried at for a second time at 35°C.

Row number	Starting weight (g)	Final weight (g)	Proportion of starting weight (%)	Proportion of original salted weight (%)
Row 1	393	303	77.1	37.6
Row 2	367	279	76.0	37.6
Row 3	436	329	75.5	39.7
Row 4	495	376	76.0	39.0
Row 5	336	254	75.6	35.2

Because the overall drying time was shorter for the salted shark fillets the reduction in weight was not as high as those which had not been salted. The moisture, water activity and plate count for large and small fillets respectively were 37.7% and 19.2%, 0.754 and 0.602, and 1.8 x 10^5 cfu/g and 5 x 10^5 cfu/g. Salt appears to be an effective treatment for controlling microbial growth during drying of shark fillets. The amount present in the end product may have to be monitored. Even with the improvement in drying a further drying of the larger fillets may be needed to ensure good shelf life. These samples were sent to a buyer for appraisal as there was no available product specifications.

Jerky

One commercial collaborator requested a drying trial of marinated shark strips. The meat was marinated overnight with a standard soy based marinate without sodium nitrite and loaded onto the load cell screens for drying at 55°C. A tray of unmarinated shark meat was also dried. The temperatures, weight changes recorded by the load cells and humidity during drying are present as Figures 7.13, 7.14 and 7.15 in Appendix 1. The weight changes for the load cell screens and the tray are presented in Table 43.

Table 43. Weight reduction for shark jerky dried at 55°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	654.3	243.7	37.3
Row 2	681.9	254	37.3
Row 3	623.7	242.9	39
Row 4	645.6	242.9	37.6
Row 5	488.7	223.1	45.7
Tray 1	163.7	49.9	30.5

ECHINODERMS

BECHE DE MER

This type of dried seafood is already produced in Australia in large amounts cost effectively using solar energy. Unless large amounts can be regularly put through a heat pump drier it is unlikely to be cost effective. To give processors some information to help decide whether it is cost effective some batches of beche de mer were dried using this technology. Several different product forms were dried.

Whole

The first batch was whole sand fish. These proved slow to dry requiring several days. The graph in Figure 8.1 shows the weight lost during this period. Table 44 shows the weight changes of each tray at the end of drying.

Table 44. Weight reduction for whole beche de mer dried at 50°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
1	1166	371	31.8
2	1028	323	31.4
3	1090	356	32.7
4	1066	343	32.2
5	362	97	26.8

The moisture content of individuals varied from 5% to 17.5%. Some of the thicker individuals still retained moisture.

Strips

The second product form was beche de mer sliced across the length of the body to produce pieces approximately 2cm thick. This product was to be milled after drying for incorporation into soups and other Asian foods. There was too much material to process in one run so it was divided into two batches. For each batch, 40kg of product was boiled for 10 minutes, then loaded onto the HPD and dried at 45°C for 17h. Figures 8.2 and 8.3 show the temperature of the material during drying of each batch.

The weight changes for the five rows of sample placed on the load cells and the humidity was recorded during drying and can be seen for batch one in Appendix 2 as Figures 8.4 and 8.5. The weights at the start and end of drying were recorded using a top pan balance. The data for both the load cell trays (rows 1 to 5) and two stainless steel larger trays (trays 6 and 7) are presented in Table 45.

Table 45. Weight reduction for batch one of beche de mer strips dried at 45°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	982	493	50.2
Row 2	964	488	50.6
Row 3	971	785	51
Row 4	998	531	53.2
Row 5	968	460	47.5
Tray 6	2372	991	41.8
Tray 7	2133	1134	53.2

Two samples were taken for analysis of moisture content and water activity. The first was dark and hard and appeared to be totally dry. It had moistures of 15.4% and 16.4% and water activities of 0.68 and 0.62. The second sample was still flexible and probably retained some moisture. These were indeed higher (26.9% and 28.2%) with the associated water activities also higher (0.87 and 0.86). These levels show that further drying was required. Because this was a commercial trial the second batch of beche de mer strips was also dried overnight at 45°C. The load cell and humidity recordings made during drying are displayed as Figures 8.6 & 8.7 in Appendix 2. The weights at the start and end of drying are presented in Table 46.

Table 46. Weight reduction for batch two of beche de mer strips dried at 45°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	983	445	45.3
Row 2	1007	436	43.3
Row 3	949	404	42.6
Row 4	987	424	43.0
Row 5	1357	592	43.6
Tray 6	1980	888	44.9

The product was stored at room temperature for two weeks in sealed bins before a second drying was commenced. As the material had been reduced considerably both batches were dried together. Table 47 contains the weight reduction data for the second drying.

Table 47. Weight reduction in beche de mer strips from batch one and batch two for the second drying at 45°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of starting weight (%)
Row 1	1.329	1.168	87.9
Row 2	1.245	1.093	87.8
Row 3	1.383	1.214	87.8
Row 4	1.409	1.236	87.7
Row 5	1.478	1.295	87.6
Tray 1	2.0	1.667	83.4
Tray 2	1.8	1.449	80.5
Tray 3	1.7	1.369	80.5

The moisture content of product from batch one (rows) ranged between 30% and 21% while that for batch two (trays) was between 29% and 21%. At the end of the second drying the moisture content was 14.5%. Figures 8.8, 8.9 and 8.10 show the temperatures, weight changes and humidity during the second drying.

MOLLUSCS

CUTTLEFISH

Whole frozen cuttlefish were split by cutting through the ventral surface taking care to keep the head attached while removing the mandible and the internal organs. The first cuttlefish drying trial was incorporated with the fish maw. Because of this it was not possible to record the changes in weight using the load cell. The operating temperature of the HPD was 45°C. The temperature profiles can be seen in Figure 9.1 of Appendix 3. Five cuttlefish weighing a total of 1403g dried to 480g giving a reduction to 34.2% of the original weight. There was still moisture evident within the flesh of the cuttlefish at the end of drying and after several days of equilibration at 2°C a second drying at 45°C for two hours was carried out. A load of 487g was reduced to 434g. The slight increase in weight after equilibration is probably due to absorption during the long storage time. The final dried weight is 30.9% of the original weight.

A supply of low priced cuttlefish was obtained from India for drying studies. The cuttle, guts and pigmented integument were already removed allowing the product to be thawed and placed directly into the HPD. Figures 9.2, 9.3 and 9.4 in Appendix 3 display the temperatures, weight changes and humidity during drying. The weight changes at the end of drying are shown in Table 48.

Table 48. Weight reduction for cuttlefish dried at 45°C.

Size	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
large	1008	385	38.2
small	397	112	28.2

SQUID

The first time squid were dried in the HPD they were for a prawn feed experiment being conducted by another QDPI branch. Unfortunately as no data other than the temperatures have been obtained. These can be seen in Appendix 3 as Figure 9.5. Small sized squid (average tube 70gm) were dried at 45°C in conjunction with the fish maw described in an earlier trial.

35°C

The next run for squid suffered from a similar problem but this time weight changes and humidity during drying (Figures 9.6 and 9.7) were obtained but without the temperatures. Approximately 30kg of split squid material was loaded onto stainless steel mesh trays while 5.696kg of uncut squid tubes (mantle) were placed on the load cell rows. The pH, moisture and water activity at the start of drying of whole tubes were 8.5, 84.5% and 0.971 and of split squid tubes were 8.83, 86.4% and 0.976. The standard plate counts for both types of squid were 4 x 10^6 cfu/g. There was very little difference between these forms as they were from the same batch of squid. The operating temperature for the HPD was 35°C. The weights of the uncut tubes at the start and finish of drying are presented in Table 49.

Table 49. Weight reduction for uncut squid tubes.

Row Number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
1	1139	217	19.1
2	1101	212	19.3
3	1156	221	19.1
4	1157	225	19.5
5	1143	217	19.0

A total of 5.789kg of dried split squid was produced from the trays which is 19.3% of the starting weight. The bacterial count, moisture and water activity for the split tubes were 3.3 x 10^5 cfu/g, 14.8% and 0.524. The uncut tubes appeared to be of lower quality.

This work continued into further bulk drying at several temperatures. The lower was 35°C and involved approximately 60kg of split squid tubes (average individual weight 70gm) placed on 32 mesh based stainless steel trays and some uncut tubes on the load cell rows. All the viscera, head and skin had been removed. The standard plate count and moisture of the raw squid were 6.3 x 10^5 cfu/g and 81.8%. The temperatures during drying can be seen in Figure 9.8, 9.9 and 9.10. The weights at the start and finish of drying are shown in Table 50.

Table 50. Weight reduction for split squid tubes.

Row Number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
mean of mesh tray	840.8	167.0	19.9
whole tubes	431	102	23.7

The standard plate count and moisture of the dried split squid were 1.9×10^5 cfu/g and 9.9% and the moisture of the tubes was 29.3%. The lower temperature is obviously less effective in drying the tubes.

45°C

The next temperature applied to split squid was 45°C. A total of 5 load cells and 34 mesh trays and 6 solid trays were loaded with the same squid prepared for the previous trial. The temperatures, weight changes and humidity during drying can be seen in Appendix 3 as Figures 9.11, 9.12 and 9.13. The weights at the start and finish of drying are present in Table 51.

Table 51. Weight reduction for split squid tubes.

Row Number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
1	762	138	18.1
2	801	152	19.0
3	799	148	18.5
4	862	158	18.3
5	847	153	18.1
mean of mesh tray	974.7	191.4	19.6
mean of solid tray	1033.7	214.2	35.7

The colour of the dried squid was darker than those dried at lower temperature. The squid placed in the solid trays were still moist and required further drying. The higher temperature resulted in a product of lower water content at 9%.

The two aspects of efficiency and quality need to be balanced. While higher temperatures dry product at a faster rate the browning of product is higher and this trait results in lower prices so it is advisable to use the lower temperature whenever possible.

Product evaluation

Shop No. 1

The manager stated that the retail consumer preferred the whole squid in dried form. This was highly important in judging the overall eating quality of the product. The heat pump dried samples appeared artificial or plastic to the eye and it was difficult to relate to from a traditional perspective. The texture of the heat pump dried sample felt correct to touch and appeared to be of equivalent moisture level or dryness to the retail product. The yellow gold colour of the heat pump sample was far to light and should be darker for consumer acceptance. The retail product appeared grey in colour and signs of a white precipitate were evident on the surface of these squid. The squid also possess striations down the entire surface giving the sample an aged appearance.

The most important difference between the heat pump dried sample and the retail sample was perceived for the aroma. The retail sample had what could be termed an "old seafood smell" in some cases slightly rancid in nature. This smell was highly important in imparting flavour to the end users traditional recipe. The heat pump dried sample, though possessing an aroma, lacked the appropriate intensity, depth and maturity required for traditional use. The manager stated that she would not buy the heat pump dried product and therefore could not provide an valuation of the sample.

Shop No. 2
The manager of this shop stated that the product was traditionally sold whole in the retail sector. Keeping the squid intact was necessary for the customer to make a decision on product quality. The colour of the heat pump sample was considered to light for the consumer. The overall appearance of the light colour and split presentation gave the impression of a artificial product. The squid also lacked the aroma traditionally expected in this style of product with greater depth, intensity and maturity development being required before it could be sold profitably. A price of about A$20 per kg could be expected for whole squid provided it had darker colour and greater intensity of aroma. In the opinion of the manager our product in current form would not be saleable to the traditional market.

Shop No. 3
In the opinion of the sales assistant at this shop the heat pump dried squid lacked aroma. The ample was pale and required with a stronger yellow colour. The texture and moisture level however were acceptable. No price or value was ventured for the product due to the difference in quality .

Shop No. 4
The assistant at this outlet stated that whole squid is required by the customer to make a purchase decision and for this reason dried squid was not sold in the split form in their supermarket. The colour of the heat pump dried squid when compared to the retail product appeared to be lighter. The aroma of the retail sample was much more pronounced in intensity and depth than the heat pump dried sample. The traditional aroma is a key factor in representing the flavour that the product will impart to the final edible dish. The heat pump dried texture felt acceptable and similar to the retail dried product. In general the heat pump sample was considered artificial or plastic in both aroma and appearance. Because of the above reasons the product would not be bought and no value could be placed on the product.

SCALLOPS

Scallops make up a large part of the market for dried seafood. They are sold either whole or in pieces. The latter are the most valuable and this aspect is dependent on size. The best quality are sold in clear plastic boxes and kept refrigerated. Tests of some product imported into Australia found a water activity of 0.64 and a moisture content of 20.4%.

Frozen scallops

The first drying trial for scallops utilised frozen product. This was the only source of raw material at the time of the trial and was used to identify when case hardening may occur. Information from the literature and industry contacts indicated that scallops are dried cooked and often involves more than one cooking. The first cook is by boiling in saline water and the second in fresh water to remove excessive salt. The scallops were blanched in boiling water for one minute. After cooling cracks were evident on the surface. The scallops were then dried overnight at 35°C. Case hardening was apparent at the end of the run and there was still plenty of water present, moisture content 34% and water activity 0.855. Table 52 shows the weights for the different treatments.

Table 52. Weight reduction for frozen scallops.

Starting weight (g)	Blanched weight (g)	Drained weight (g)	Dried weight (g)	Proportion of original weight (%)
245.2	188.9	182.0	53.0	21.6

The temperatures, weight changes and humidity during drying are presented in Appendix 3 as Figures 10.1, 10.2 and 10.3. The appearance of the dried scallops was quite poor with loss of shape due to moisture being retained in the centre. The data suggests a maximum of 5 hours continual drying is only possible before defects develop. Frozen scallops should not be dried using a heat pump drier.

Constant drying fresh scallops

Freshly harvested scallops, kept in refrigerated seawater before processing and then stored chilled (<0°C), were obtained for further trials. The starting moisture content, water activity and pH were 83.9%, 0.973 and 6.6. Because of the high cost of scallops only 1kg of scallops were used per trial. The size of the scallops were 40/60 count per pound.. The scallops were cooked by immersion in boiling salted water (3%NaCl) for one minute and then left to drain for 5 minutes. After cooking the moisture content, water activity and pH were 81.4%, 0.973 and 6.6. The scallops were then placed in the drier for 4 hours at 35°C and then cooked for one minute for a second time using water with no salt. The scallops were then stored overnight at 1°C before a second drying was conducted. Table 53 shows the changes in weight due to the different treatments. As samples were removed after cooking and drying the weight changes are reported as percentages of original weight.

Table 53. Weight recovery for fresh scallops.

Treatment	1st cook	drained	1st dry	2nd cook	2nd dry
Recovery (% original)	86.2	70.6	39.9	41.3	16.2

The moisture content and water activity at the end of drying were 24.2% and 0.662. An electrical fault interfered with the temperature recording on the first drying resulting in data for only the first hour of the trial. The temperatures, weight changes and humidity during the first and second drying can be in Appendix 3 as Figures 10.4 through to 10.9. The appearance of the dried scallops was poor with loss of shape due to moisture being retained in the centre of some scallops. The colour was golden with little browning present.

Intermittent drying of fresh scallops

Two minute cook

Scallops from the previous batch were cooked by boiling in 3% NaCl water for 2 minutes. After draining for 5 minutes they were placed in the drier which ran for 3 hour at 35°C followed by a shut down for 3 hours. This occurred for 3 cycles then the scallops were removed and cooked a second time for 2 minutes in salt free water. The scallops were then returned to the same drying regime for another 3 cycles. Table 54 shows the weight changes for the drying run.

Table 54. Weight recovery for fresh scallops dried intermittently.

Treatment	1st cook	drained	1st dry	2nd cook	2nd dry
Recovery (% original)	76.6	70.3	23.4	24.9	16.6

The moisture content and water activity at the end of drying were 24.6% and 0.66. The low water activity will ensure good shelf life even though there is still a moderate water content. The temperatures, weight changes and humidity during the first and second drying are shown in Appendix 3 as Figures 10.10 through to 10.15. Approximately half of the batch appeared to be adequately dried. As there was some sagging of the tissue in the centre the initial drying conditions were still too rapid, resulting in case hardening. This indicates that shorter periods of drying were required.

Four minute cook

The effect of cooking time was investigated in an attempt to reduce the collapsing of the central section of the scallop. An increase to a 4 minute boiling time would induce more hardening of the muscle fibres and thus provide better support of the tissue as it dried. The pH, water activity and moisture content prior to cooking was 6.04, 0.97 and 83.3%. These parameters after cooking were 6.81, 0.97 and 79.9%. The initial drying after cooking started with 4 hours drying at 35°C followed by 4 hours of equilibration. This operation was repeated for 3 cycles with no second cooking stage. Table 55 displays the weight changes from the raw form for each treatment.

Table 55. Weight recovery for fresh scallops dried intermittently.

Treatment	1st cook and drain	dried
Recovery (% original)	75.9	20.9

The temperatures, weight changes and power consumption and humidity during drying can be seen in Appendix 3 as Figures 10.16 through to 10.18. The water activity and moisture content after drying were 0.71 and 24%. The colour of the scallops was golden but there was still substantial collapse of the central area. The time for each cycle needs to be reduced.

Four minute cook, dry, second cook (two minute), second dry

The raw scallops had a water activity of 0.95 and moisture content of 82.3%. After 4 minutes boiling time they had a water activity of 0.96 and moisture content of 73.8%. The initial drying for this cooking time started with one hour of drying at 35°C followed by one hour of equilibration. This operation was repeated for 4 cycles with a second cooking stage of two minutes boiling time in fresh water. The latter is used to reduce the salt content which becomes concentrated with drying. Table 56 displays the weight changes from the raw form for each treatment.

Table 56. Weight recovery for fresh scallops dried intermittently.

Treatment	1st cook and drain	1st dry	2nd cook and drain	2nd dry
Recovery (% original)	66.9	35.7	38.75	21.7

The temperatures, weight changes and power consumption and humidity during the first and second drying can be in Appendix 3, Figures 10.19 - 10.21. The water activity and moisture content of the dried scallops were 0.76 and 28%. The colour of the scallops was golden and there was little collapse in the centre. The conditions applied in this trial were the most suitable to producing dried scallops with an adequate shape and minimal distortion. Further refining of the method was investigated in the following trial.

Three minute cook, dry, second cook (two minute), second dry

A reduction of initial cooking time was the next modification investigated. Raw scallops with a water activity of 0.95 and moisture content of 82.3% were cooked with a boiling time in 3% salt water of 3 minutes. After cooking the water activity and moisture content were 0.96 and 76.6%. The initial drying for this cooking time started with one hour of drying at 35°C followed by one hour of equilibration. This operation was repeated for 4 cycles with a second cooking stage of two minutes boiling time in fresh water. Table 57 gives the weight changes from the raw form for each treatment.

Table 57. Weight recovery for fresh scallops dried intermittently.

Treatment	1st cook and drain	1st dry	2nd cook and drain	2nd dry
Recovery (% original)	78	47.2	51.24	22.3

The weight changes and power consumption and humidity during the first drying are shown in Appendix 3 as Figures 10.22 and 10.23. Difficulties with the electrical system caused the loss of some data. The water activity and moisture content of the dried scallops were 0.76 and 28%. The colour of the scallops was golden and there was some collapse in the centre of the scallop after drying. The conditions applied in this trial were thus unsuitable to producing dried scallops because of the distortion that was present. A minimum of 4 minutes boiling time is required before any drying of scallops in the heat pump drier should be attempted.

Product evaluation

Shop No. 1
The heat pump dried scallops appeared lighter in colour and smaller in size then the samples traditionally traded. The aroma of the heat pump sample was considered inadequate and lacked the depth, intensity and maturity usually expected of the product. The slightly collapsed centres of the heat pump dried sample did not appear to be a factor in establishing sample quality. The heat pump sample was considered excessively dried with the comment that it lacked the usual levels of pliability expected of retail scallops. The heat pump samples were considered too small in size and light in colour to provide an evaluation. The manager stated that she would not buy the heat pump dried samples in its current form.

Shop No. 2
This manager provided the information that the best and largest quality scallop originated in Japan. In this outlet it was sold as small presentation packs. The Chinese scallop was smaller then the Japanese scallop and of relatively good quality. The scallops originating from Vietnam were at present small and poor in quality with sand contamination being a major issue. The heat pump dried sample was considered to be small, far too light in colour and lacking in the traditional aroma expected. The aroma should be "older and more developed" for the traditional buyers to purchase. The heat pump sample was also considered too dry for the retail market with the texture considered to be lacking pliability. The heat pump dried samples were considered acceptable for soups but not for stand alone sale. The manager stated that she would not buy the heat pump dried sample and therefore could not place a value on the product.

Shop No. 3
At the third shop the heat pump dried sample was considered to be too small in size. The depth of colour and the aroma of the sample was not considered correct or strong enough for a saleable product. The slight depression present in the heat pump dried scallops did not appear to be an issue in the purchasing quality of the scallop. No price or value was ventured for the product due to the difference in quality indicators as mentioned above.

Shop No. 4
The manager of the fourth shop stated that the size of the heat pump scallop was considerably smaller than that which is traditionally sold in shops. The colour of the retail product was a caramel brown whilst the heat pump sample was yellow. The assistant suggested that the difference

in colour would reduce the saleability of the heat pump dried sample. The heat pump dried sample was considered to be overdried because of the harder texture. A moisture comparison of the retail product and heat pump sample supported this opinion with a greater then 7% difference in moisture content detected between the two samples. The slightly depressed centres of the heat pump dried samples did not appear to be of importance to the assistant. The difference in intensity and depth of aroma were important factors in the consumer decision to purchase scallops. In comparison the heat pump dried sample lacked the type, intensity and depth of aroma required for traditional consumers. This aroma is an important factor in imparting flavour to the final prepared meal. A comparison between the scallops offered for sale and those dried by heat pump found that the retail sample clearly exhibited a complex marinated, mature flavour not too dissimilar to soy sauce whilst the heat pump sample exhibited a much milder flavour with little complexity. The relationship was akin to tasting smoked fish and steamed fish where smoking has imparted some complex and synergistic flavours whilst steaming generally relies entirely on the initial qualities of the fish.

PEARL MEAT

A limited sample of meat containing the adductor muscle and mantle from the winged pearl oyster *Pteria penguin* was forwarded from a culturist in Western Australia for drying trials. This material is a valuable by-product of the pearl industry and up until recently was dumped or given to staff to take home. The methods developed for scallops are suitable for pearl adductor muscle.

Raw

As only a small amount of material was obtained both types of tissue were dried at the same time. These were loaded uncooked and dried at 35°C. The temperature profiles are present in Figure 11.1. Unfortunately due to power failure no data was obtained from the load cells or humidity sensors. The weight changes are shown in Table 58.

Table 58. Weight reduction for raw pearl meat dried at 35°C.

Type of tissue	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
muscle	377	59.8	15.9
mantle	443	157.4	35.5

There was still moisture trapped within the tissue of the adductor muscle (moisture content of 32.2% and water activity of 0.842) requiring, after some equilibration, a second drying. The mantle was quite dry with a moisture content of 8.8% and a water activity of 0.359. Only the adductor muscle was dried a second time at 45°C. The temperatures, weight changes and humidity during drying can be seen in Appendix 3 as Figures 11.2, 11.3 and 11.4. The amount of material placed in the drier was too light to produce accurate load cell measurements. The weight changes are present in Table 59.

Table 59. Weight reduction for raw pearl meat for second drying at 45°C.

Type of tissue	Starting weight (g)	Final weight (g)	Proportion of starting weight (%)	Proportion of original weight (%)
muscle	144	113	78.5	12.5

The moisture was reduced to 15.2% and the water activity to 0.463 and this level of drying is suitable for good shelf life of this product.

Cooked

Another drying trial for pearl meat used cooked material. Both types of tissue were cooked by immersion in boiling 3% NaCl brine for 3 minutes prior to drying. The temperature profiles, load cell measurements and humidity readings are present as graphs in Figures 11.5, 11.6 and 11.7. The weight changes are shown in Table 60.

Table 60. Weight reduction for cooked pearl meat dried at 35°C.

Type of tissue	Raw weight (g)	Cooked weight (g)	Dried weight (g)	Proportion of original weight (%)
muscle	319.5	218	85	26.6
mantle	208.1	100	26	12.5

There was still moisture (26.5%, water activity 0.809) trapped within the tissue of the adductor muscle requiring a second drying after some equilibration. The mantle was much drier with a moisture content of 7.4% and water activity of 0.34. The adductor muscle was dried a second time after a lengthy equilibration time. The 72g of material loaded for drying at 45°C was reduced to 66g, 91.7% of the starting weight and 24.4% of the original wet weight. The moisture content was 15.8% and water activity was 0.663. The cooked product had a lighter colour and better shape after drying than the raw material. The yield is also much higher for the cooked product. The graphs depicting temperatures, weight changes and humidity during the second drying are present in Appendix 3 as Figures 11.8, 11.9 and 11.10.

Product evaluation

Shop No. 1, 2 & 3
No information was available on this type of product as it was not sold by these particular outlets.

Shop No. 4
The assistant at this shop considered the colour of the heat pump sample very acceptable. The assistant commented that dried pearl meat tends to change its colour during storage. The heat pump sample retained a red-brown colour while in comparison the retail sample appeared matt black. It was commented that the size of the heat pump dried samples needed to be slightly larger or thicker for traditional customer acceptance. The collapse of the centre of the meat during heat pump drying had produced a thinner sample. The heat pump dried pearl meat retained an acceptable aroma and was considered superior to the retail samples on sale. This came as quite a surprise as the sample presented was in our assessment not of high quality. The retail price for dried pearl meat was indicated as being about A$500 per kg.

While the drying of Queensland scallops is not economically feasible the development of procedures for this product were finalised so that they can be applied to the similar material of pearl adductor muscle. Unfortunately further samples of pearl meat could not be obtained to confirm that this method is adequate.

Cooked and intermittently dried

A final sample of wild pearl adductor muscle was obtained from the company Le Mer Marketing and Consultancy Pty Ltd for testing the intermittent method developed using scallops. While raw material is currently difficult to obtain, the aquaculture of pearl oysters is an expanding industry. The company that supplied this meat projects that it will be harvesting 17,000 shell a year in 5 years time. The sample size used for this trial was small because the pearl shells were collected from the wild. The size of meat produced from aquaculture will be much larger.

The pearl muscle was removed from the shell and cooked in seawater using a 4 minute boiling time. The weight loss due to cooking was from 2kg to 1.6kg. The cooked recovery (80%) was much higher than that obtained in the previous trial. The meat was chilled and sent to the laboratory for drying. Due to other project demands on the heat pump dryer the cabinet was modified to a smaller chamber. As the conditions could have been changed quite markedly from any of the original trials the sample was divided and the intermittent method applied. The 147 individual pieces had a range of sizes and thickness. The average weight of the large pieces was 7.8g with a moisture of 72.9% and water activity of 0.98 while the small ones were 2g, 72.3% and 0.98 respectively.

The pearl meat was placed in the HPD and dried at 35°C using an intermittent cycle of one hour drying and one hour equilibrating. After 4 cycles the pearl meat was removed and cooked a second time. Prior to cooking the meat exhibited some case hardening due to excessive drying. This disappeared after the second boiling but splits did develop on the cut surfaces of the pearl muscle. The temperature profiles, the load cell measurements and power readings and the relative humidity levels are present as graphs in Figures 11.11, 11.12 and 11.13. The weight changes are shown in Table 61.

Table 61. Weight reduction for cooked pearl meat dried at 35°C.

Type of tissue	1st Cooked weight (g)	1st Drying weight (g)	2nd Cooked weight (g)	2nd Dried weight (g)	Proportion of original weight (%)
muscle	643	379	424	190	23.6

Table 62 gives the quality parameters for the dried pearl meat.

Table 62. Moisture, water activity and bacterial count of dried pearl meat.

Size	Moisture content (%)	Water activity	Total plate count (cfu/g)
small	7.93	0.371	1×10^4
large	15.77	0.702	1×10^4

WHELK MEAT

A sample of whelk meat was obtained from an Indian company. Thawing the frozen whelk meat (2460.4g) resulted in drip loss of 20.9% (1946.3g). The pH at this stage was quite high at 8.26. The moisture content at this point was 77.9%. The meat was washed and cooked in 3% NaCl for 4 minutes to give a cooked weight of 1579.4g, a reduction to 81.2% of the raw material. The meat was dried at 45°C to a moisture of 15.9% and a water activity of 0.72. The charts containing the temperatures, weight changes and humidity during drying are present in Appendix 3 as Figure 12.1, 12.2 and 12.3. Table 63 presents the weight losses encountered.

Table 63. Weight reduction for whelk meat dried at 45°C.

Row Number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	828	265	32
Row 2	728	229	31.5

CRUSTACEA

PRAWNS

Several species of prawns were dried.

Domestic product

Cooked coral prawns were divided into two batches; one left whole and the other peeled. The peeled prawns (547.4g) resulted in a yield of 206.5g , a reduction to 37.7% of the original material. After drying at 45°C overnight, this weight reduced to 53g (25.7% of the peeled meat and 9.7% of the shell-on material). The unpeeled prawn's weight reduced from 418g to 122g, 29.2% of the original weight. The final moisture content was 8.75%. The temperature profile is present in Appendix 4 as Figure 13.1.

A second supply of cooked coral prawns were obtained from the Northern Territory. The frozen prawns were thawed and dried whole unpeeled at 35°C. Figures 13.2, 13.3 and 13.4 depict the temperatures, weight changes as detected by the load cells and humidity during drying. Table 64 shows the weight changes that occurred during drying.

Table 64. Weight reduction of cooked domestic prawns dried at 35°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	508	128	25.2
Row 2	516	128	24.8
Row 3	734	185	25.2
Row 4	800	291	25.1
Row 5	795	197	24.8

Imported product

Another supply of low price prawns from India was obtained. This consisted of small prawns with a range of sizes. They were frozen in 2kg blocks, peeled undeveined (PUD) and of size counts of 150/200, 200/300 and 300/500 per kilogram.

Prawns dried at 35°C.

The first samples trialed were of the 150/200 size. The weight after thawing and removal of drip was 2191g. The recovery after cooking in boiling 3% NaCl brine for 3 minutes was 1415g, 64.6% of the raw material. The temperature profiles, weight changes and humidity during drying at 35°C can be seen as graphs in Figures 13.5, 13.6 & 13.7 in Appendix 4. The weight changes obtained are presented in Table 65.

Table 65. Weight reduction of cooked imported prawns dried at 35°C.

Row number	Wet weight (g)	Dried weight (g)	Proportion of original weight (%)
Row 1	546	159	29.1
Row 2	581	164	28.2
Row 3	166	42	25.3

The sample had a water activity of 0.735 and the moisture content of 22.8% was still too high. As the market requires 15% moisture content, a second drying at 35°C for two hours was conducted. The weight was reduced from 344g to 307g which is a reduction to 89.2% and 23.4% of the original wet weight. The water activity was reduced to 0.545 and moisture to 13.6%.

Prawns dried at 45°C.

Another batch of prawns of 100/200 count was prepared for drying at 45°C. Thawing led to a reduction to 84% of the frozen sample and cooking in 3% brine for 3 minutes before drying reduced the weight to 53.3% of the raw thawed material. The temperature profiles, weight changes and humidity recording can be seen in Appendix 4 as Figures 13.8, 13.9 and 13.10. The weight at the start was 247g and was reduced by the drying to 80g, a reduction to 32.4% of the original.

Prawns dried at 55°C.

A small batch of already cooked PUD small prawns (300/500 count) labelled as the Indian species Karikadi were then trialed. A frozen weight of 511.2g yielded a drained weight of 359g, a reduction to 70.2%. These prawns started with a moisture of 86.5% were dried at 55°C. The final moisture content was 9.6% and a water activity was 0.38. The weight at the start was 359g and this was reduced by the drying to 55g, a reduction to 15.3% of the original. The temperature profiles, weight changes and humidity during drying are present in Appendix 4 as Figures 13.11, 13.12 and 13.13.

Two batches of larger sized cooked, PUD prawns were also dried at this temperature. One batch contained a total of 396g of prawns with a size count of 200/300 had moisture levels of 85.6% and water activity of 0.996 were dried for 5 hours to produce a yield of 71g (17.9% of original weight) with a moisture content of 18.5% and water activity of 0.74. The temperature profiles, weight changes and humidity during drying are present in Appendix 4 as Figures 13.14, 13.15 and 13.16.

The next batch (404g) of even larger PUD prawns, count 100/200, with moisture levels of 85% at the start of drying were dried for 5 hours to produce a yield of 71g (17.6% of original weight) with a moisture content of 16.7% and water activity of 0.705. The temperature profiles, weight changes and humidity during drying are present in Appendix 4 as Figures 13.17, 13.18 and 13.19.

The salt content of this batch was compared with a locally sold imported product. The heat pump dried prawns had a 2.3% NaCl content while the commercial sample contained 4.7% NaCl.

BENEFITS

The main sectors of the industry that will directly benefit are those involved in drying seafood, producing speciality seafood products or those anticipating investment in drying technology. There are considerable benefits to be gained in the drying of seafood products. Decreases in storage, transport and packaging costs are significant for dried relative to chilled and frozen products.
Increased returns can be obtained through drying as a value adding process to products that already are quite valuable, eg. scallops, abalone. It can also be used to add value to minor by-products. The following examples are based on the best information available from industry contacts. Prices are variable and process costs have not been calculated. Product size, colour and shape also affect price and marketability but the potential for improved return seems evident.

The species identified in the benefits section of the original project proposal as prospects for heat pump drying did change during the operation of the project. From interviews conducted during the overseas market evaluation it became apparent that buyers in Hong Kong and Taiwan did not want to buy dried mullet gizzard but preferred it frozen. Because of the better handling conditions present in

Australia the gizzard was of much better quality in this form. The buyers also said that there was a change in demand by consumers to non-dried gizzard.

From the experiments it became apparent that the heat pump drier was not effective at drying dense or thick products and case hardening quickly developed. A computer controlled drying device for processing abalone has been developed by Japanese researchers and this technology was kept tightly controlled. A machine was apparently obtained by Australian industry and did operate in Tasmania some years ago but has since been idle. As the equipment presently being used in this project had little automation and no humidity control, developing a drying method for abalone would have been very involved and have taken more time than the technical component had available and consumed more than that allocated for raw materials. It was for these reasons that this commodity was left out of the experimentation. It allowed time to examine a wide range of other seafood as prospects for heat pump drying as requested by industry. Scallops were retained as a commodity for experimentation to determine the suitability of using Australian material and to use as a model for the drying of pearl adductor muscle, a commodity which receives very good prices.

The size of return from dried seafood is largely dependent upon the cost of raw material. The value of a species can be maximised by drying them when there is an excess supply. Many Australian species are seasonal with gluts causing dramatic price drops. The cost of buying supplies for drying would then be kept at reasonable levels by buying at these times.

As suggested by one processor who also imports large amounts of seafood into Australia, there is no economic reason why cheap overseas supplies could not be utilised in the off season to continue processing year round.

The drying process can be carried out by either a seafood processor who purchases a heat pump drier or by a dedicated drying facility which processes the seafood under contract. This allows benefits to be shared by both sectors.

Flow of benefits

Fisheries Managed by		Australian Fisheries Management Authority	
New South Wales	12.5	Scallop	20
Queensland	12.5	Abalone	20
Northern Territory	12.5	Small fish	20
Western Australia	12.5	Prawn	10
South Australia	12.5	Squid	15
Victoria	12.5	Roes	10
Tasmania	12.5	Beche de mer	5
Other Beneficiaries (eg grains producers)			100
Total for all Fisheries	100		
Other Beneficiaries			
Total			100

Industry Collaborators

A large number of companies offered to collaborate on this project. Their participation ranged from the supply of raw material, access to raw material, information about product specifications, sample appraisal to market contacts. A list of all the contacts made and their pertinent information has been presented in previous reports and is present in Appendix 6.

Domestic consumers will also benefit from the processing of seafood by heat pump driers in Australia due to the quality that can be produced and the cost advantage of selling locally. In some Asian countries dried seafood is perceived as processed and can attract high import tariffs. The domestic market survey found that at present there is little locally produced dried seafood being sold. To satisfy the demand for this type of commodity poor quality product is being imported. This material is usually produced in another Asian country and packaged in Hong Kong for distribution which leads to long storage times before becoming available to the consumer.

INTELLECTUAL PROPERTY

No intellectual property was identified during the experimental component of this project. The report produced from the market study, however was identified as quite valuable and the researchers had so many enquires for copies that the Australian Seafood Extension and Advisory Service was given the responsibility of disseminating the report. This has been updated to include 1996 data.

FURTHER DEVELOPMENT

It would be appropriate to conduct further drying experiments on pearl adductor muscle to confirm that the methods developed for scallops would produce a high quality product.

STAFF

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A. Bremner, Senior Principal Scientist
R.Mason, Senior Lecturer
R. Naidoo, Laboratory Technician
B.Wijesinghe, Engineer

FINAL COST

A copy of the project account balances up to 30/6/1996 accompanies this report in Appendix 5.

APPENDIX 1 FISH & FISH VISCERA

Figure 1.1

Temperatures during drying of pilchards at 35°C

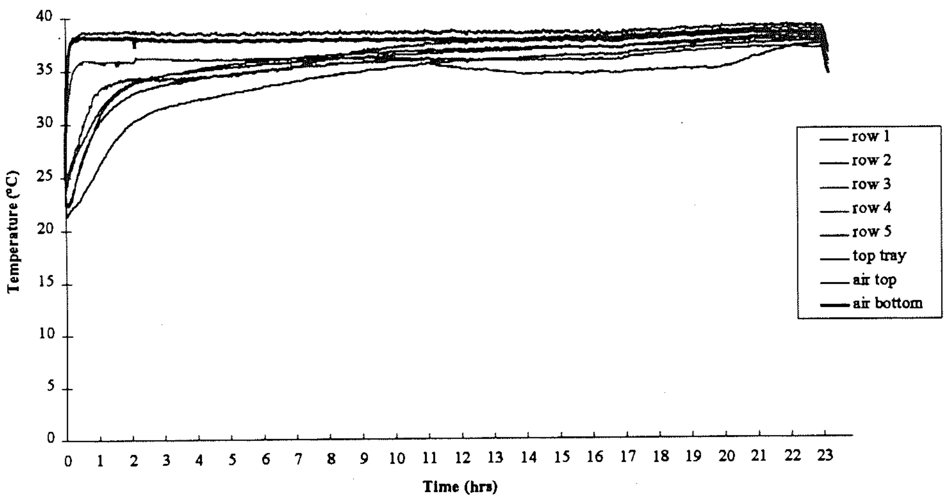


Figure 1.2

Weight changes during drying of pilchards at 35°C

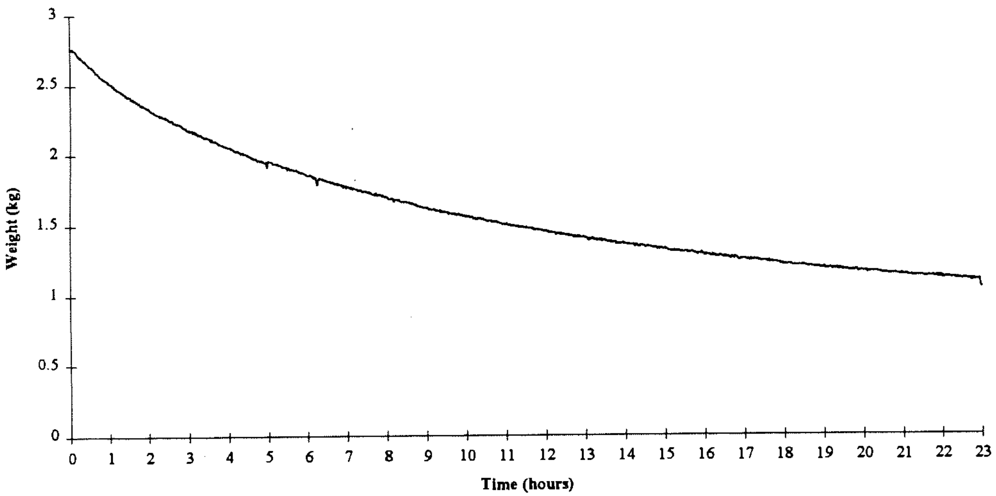


Figure 1.3

Humidity of air during drying of pilchards at 35°C

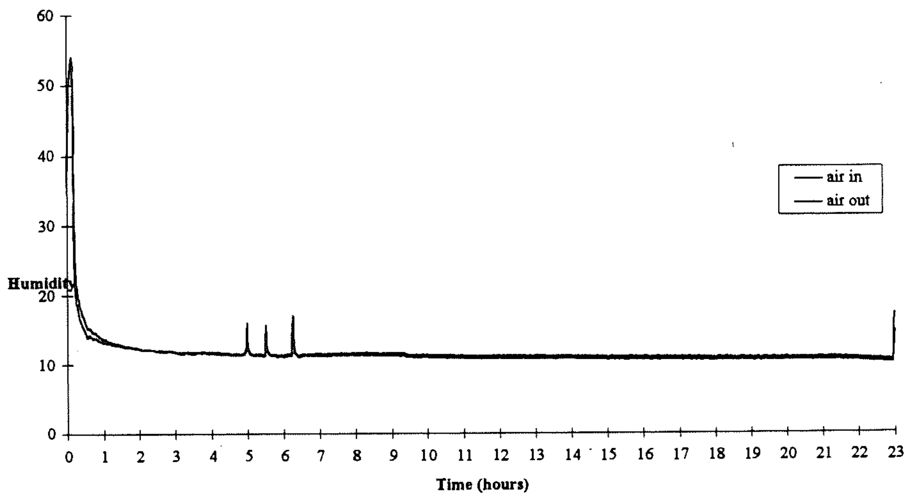


Figure 1.4

Temperatures during drying of pilchards at 45°C

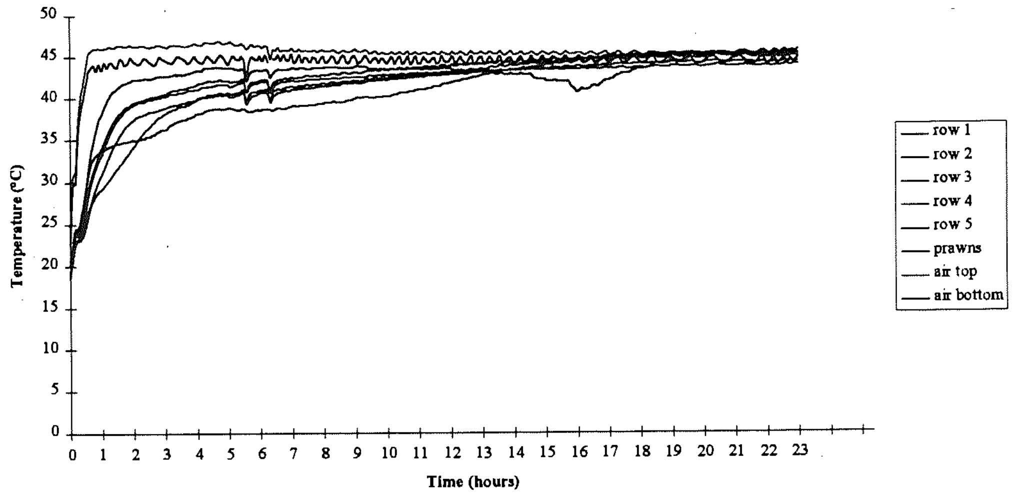


Figure 1.5

Weight changes during drying of pilchards at 45°C

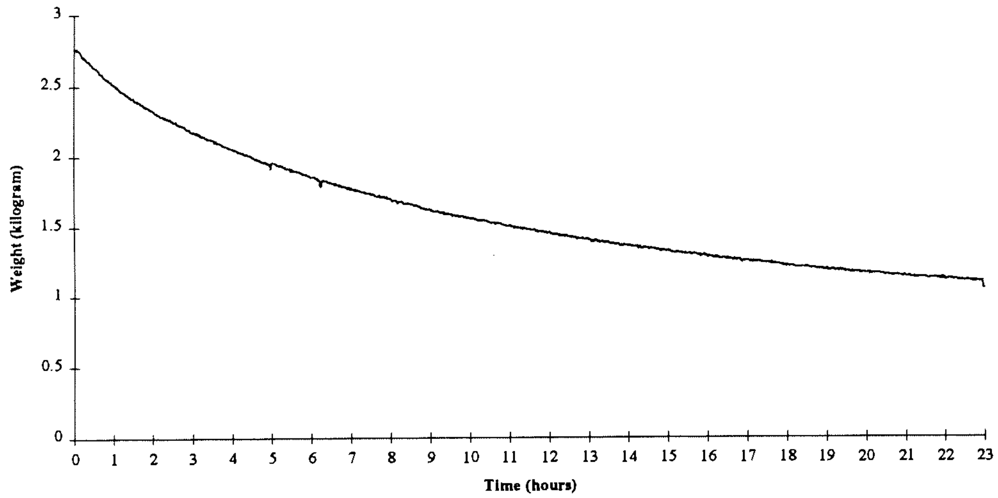


Figure 1.6

Humidity of air during drying of pilchards at 45°C

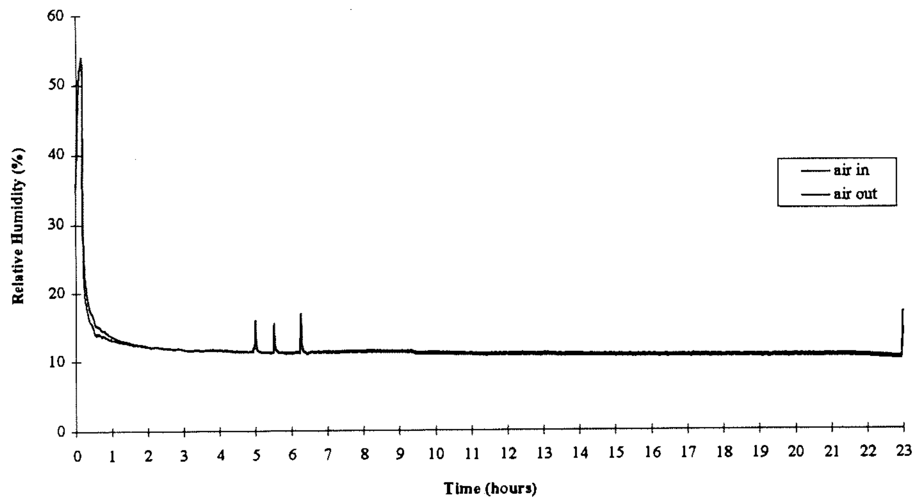


Figure 2.1

Temperatures during drying of anchovy at 35°C

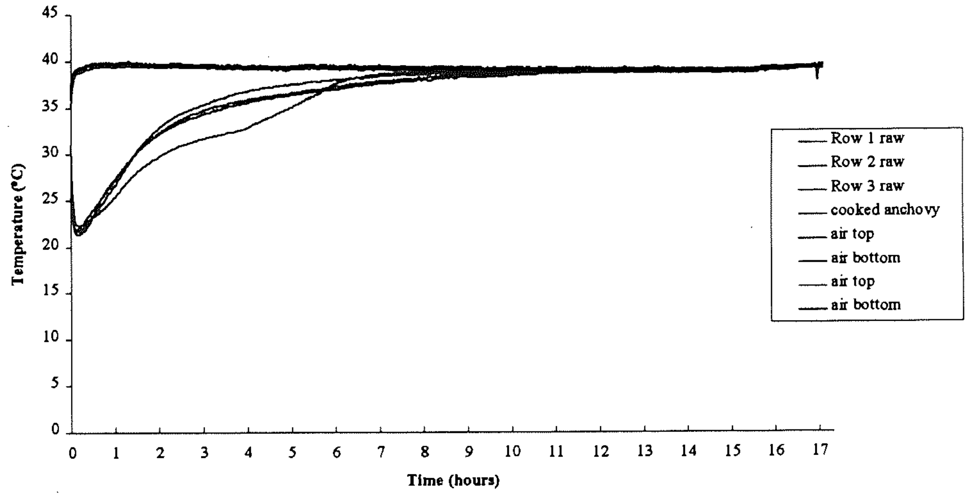


Figure 2.2

Temperatures during drying of white sardine at 55°C

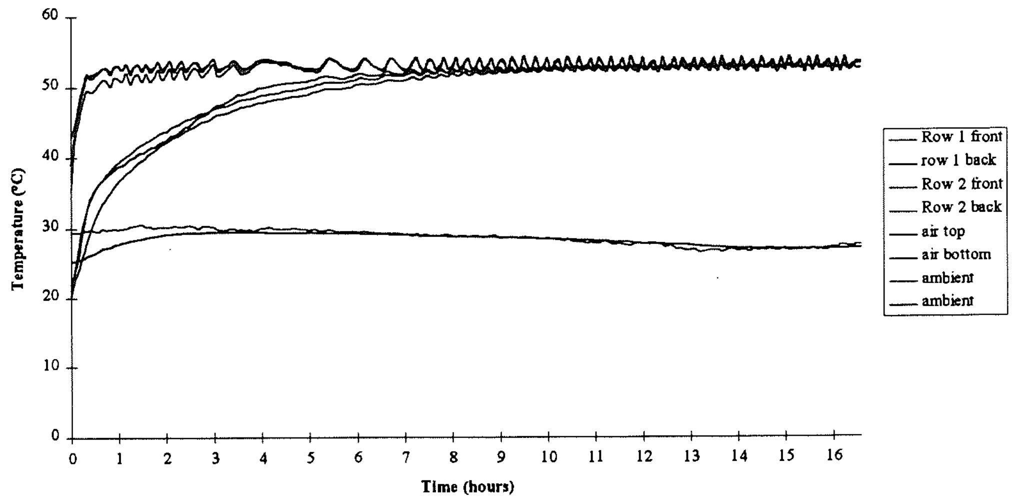


Figure 2.3

Weight changes during drying of white sardines at 55°C

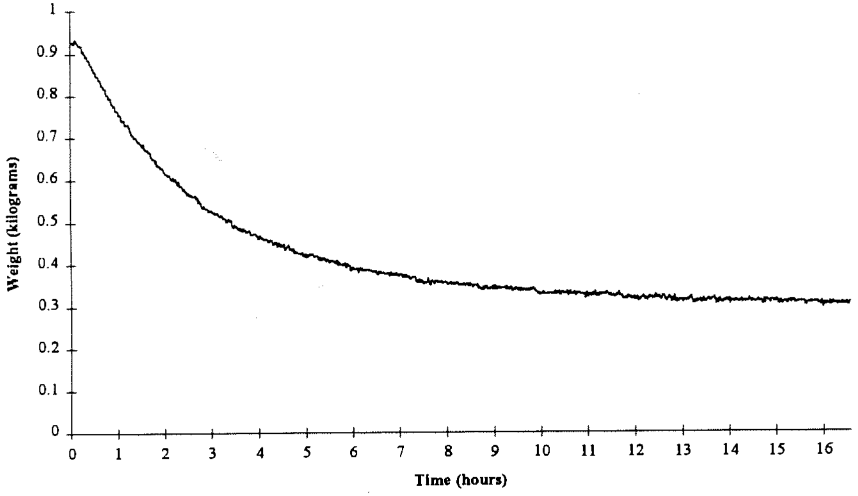


Figure 2.4

Humidity during drying of white sardines at 55°C

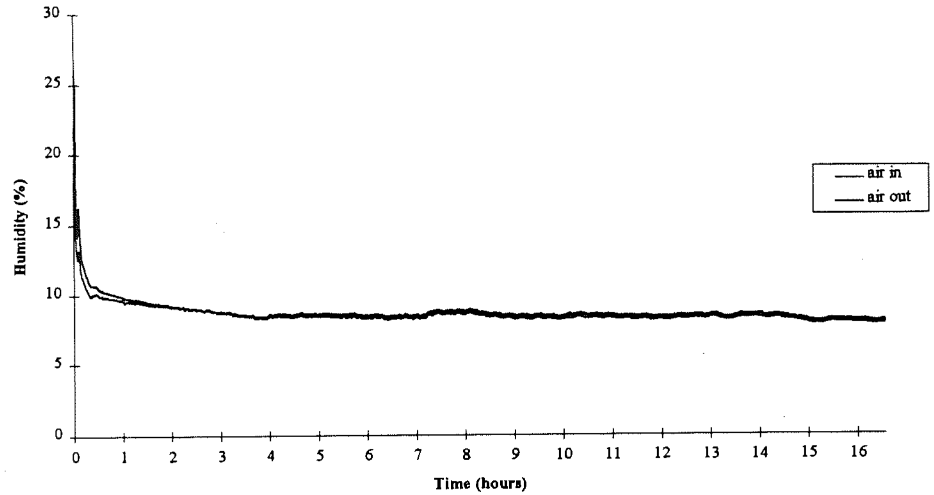


Figure 3.1

Temperatures during drying of whitebait at 35°C

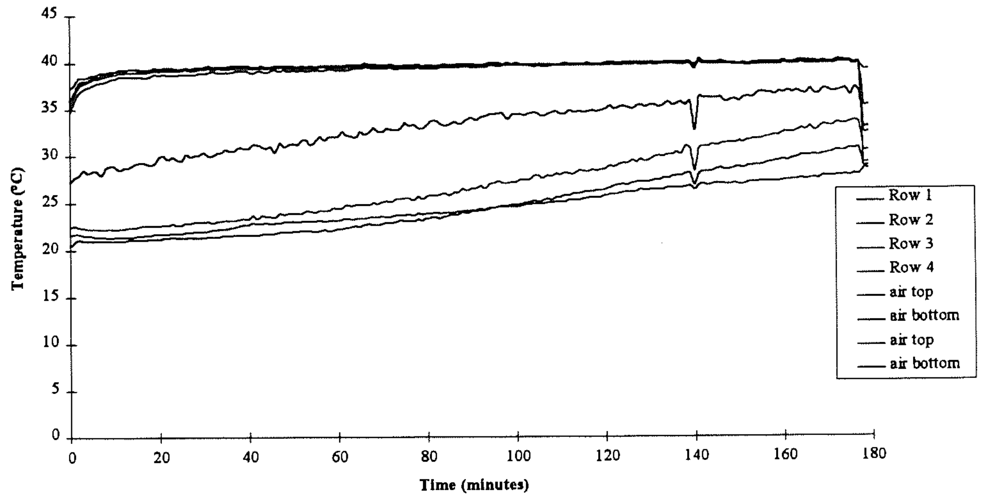


Figure 4.1

Temperatures during drying of Australian salmon at 35°C

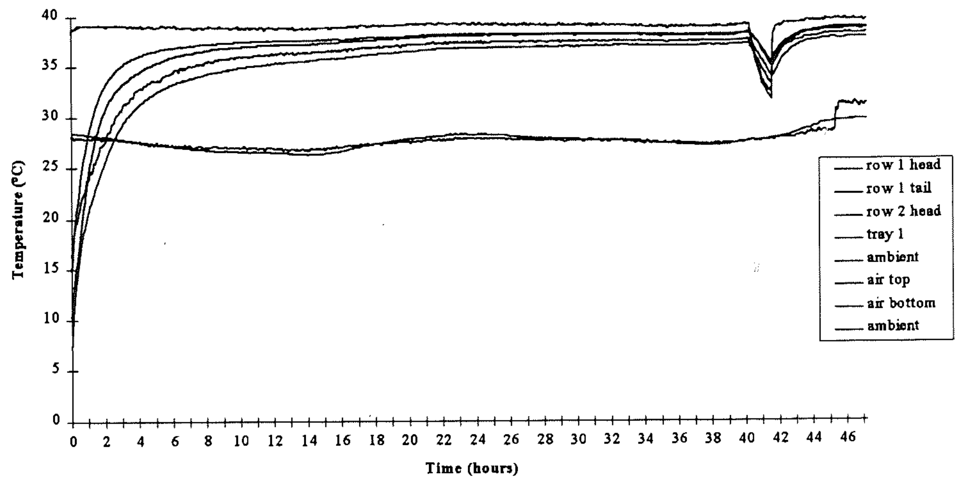


Figure 4.2

Weight changes during drying of Australian Salmon at 35°C

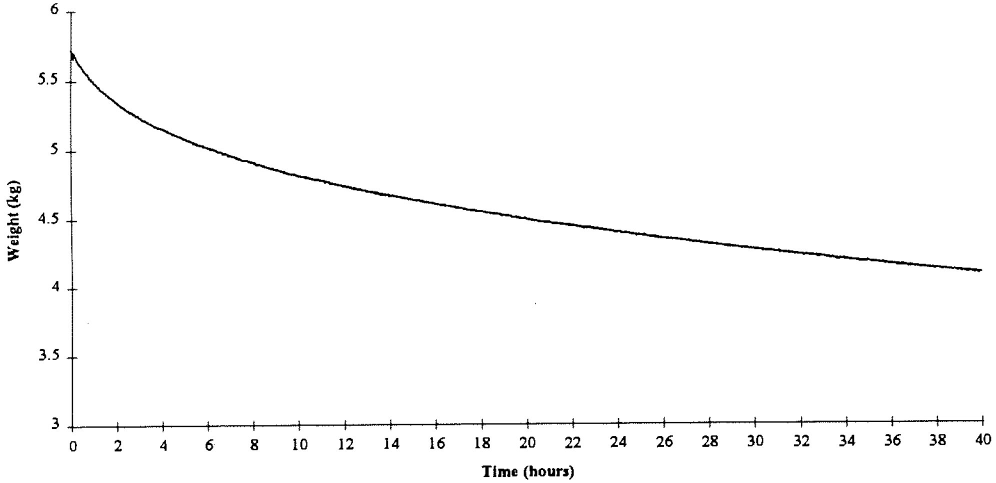


Figure 4.3

Humidity of air during drying of Australian salmon at 35°C

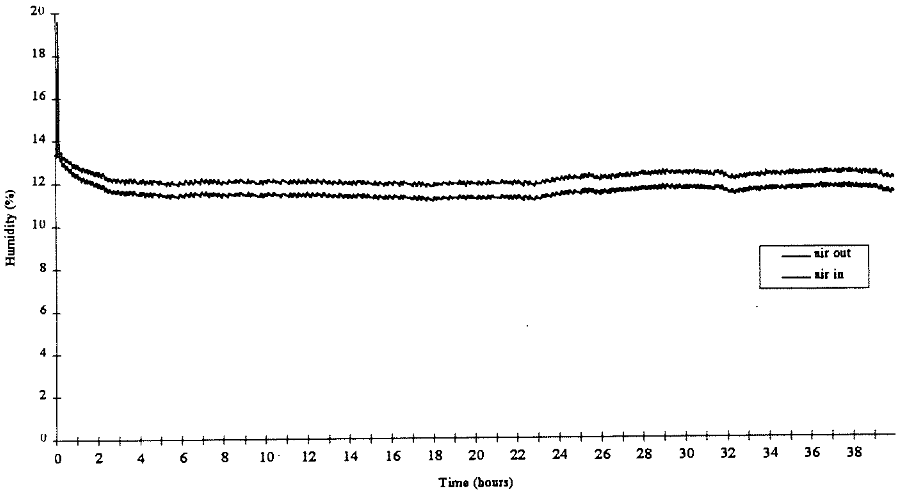


Figure 4.4

Temperature during second drying of Australian salmon at 45°C

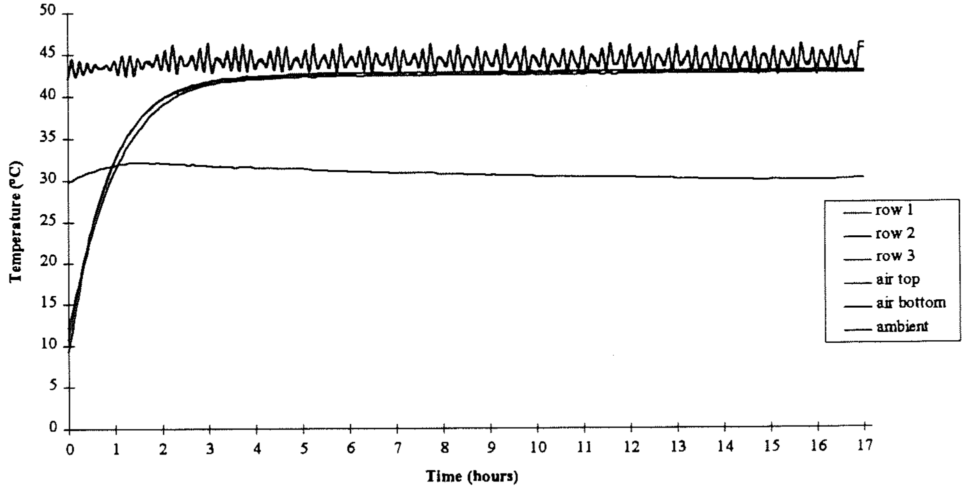


Figure 4.5

Weight changes during second drying of Australian salmon at 45°C

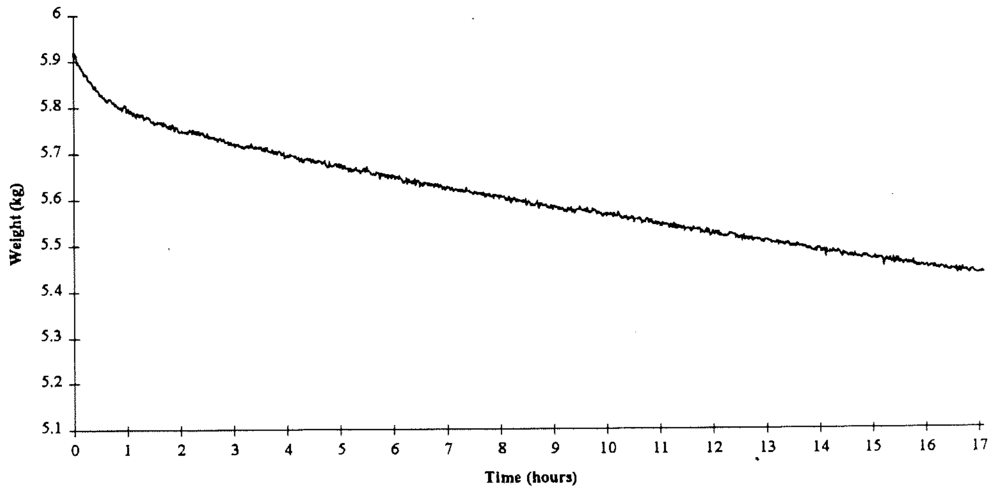


Figure 4.6

Humidity during second drying of Australian salmon at 45°C

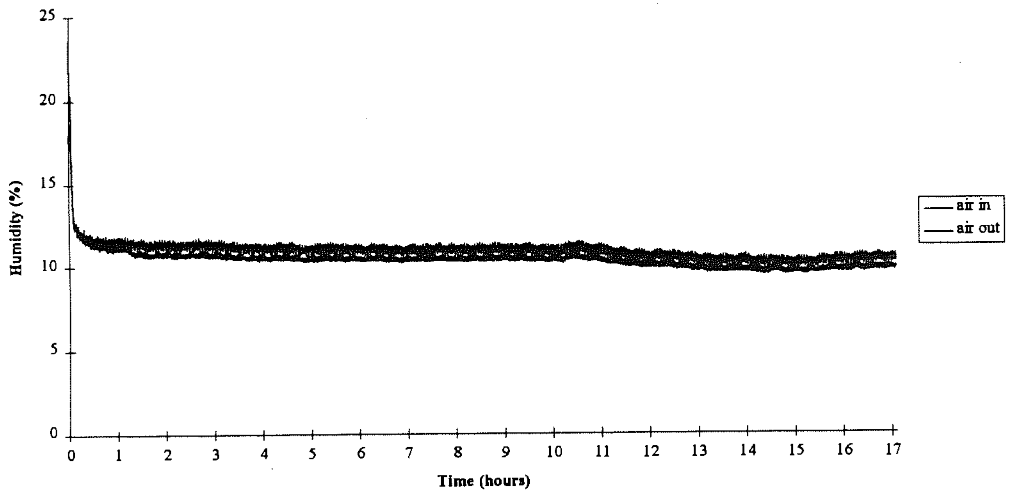


Figure 5.2

Weight changes during drying of split mullet at 50°C

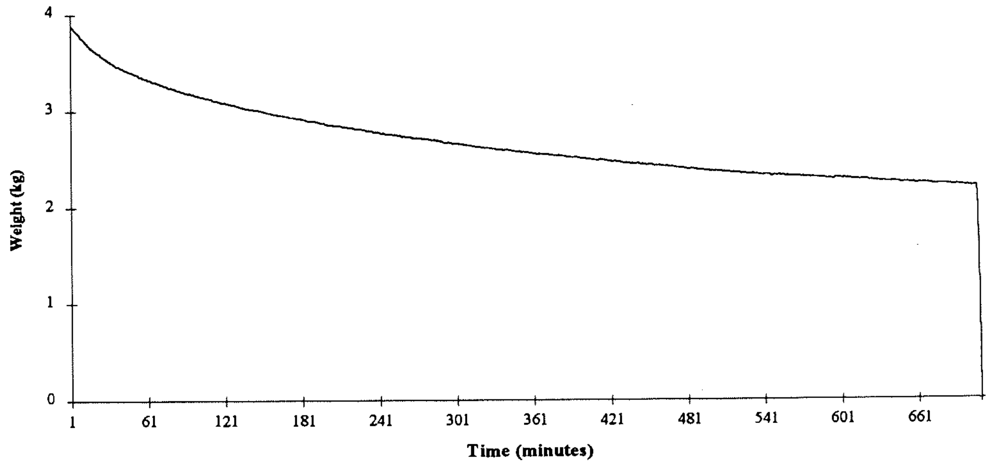


Figure 5.1

Temperature during drying of split mullet at 50°C

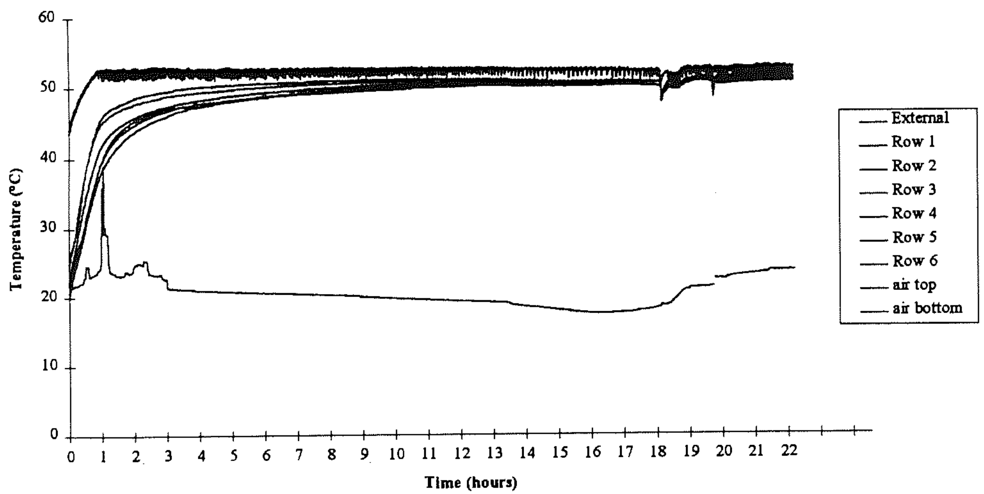


Figure 5.3

Humidity of air during drying of split mullet at 50°C

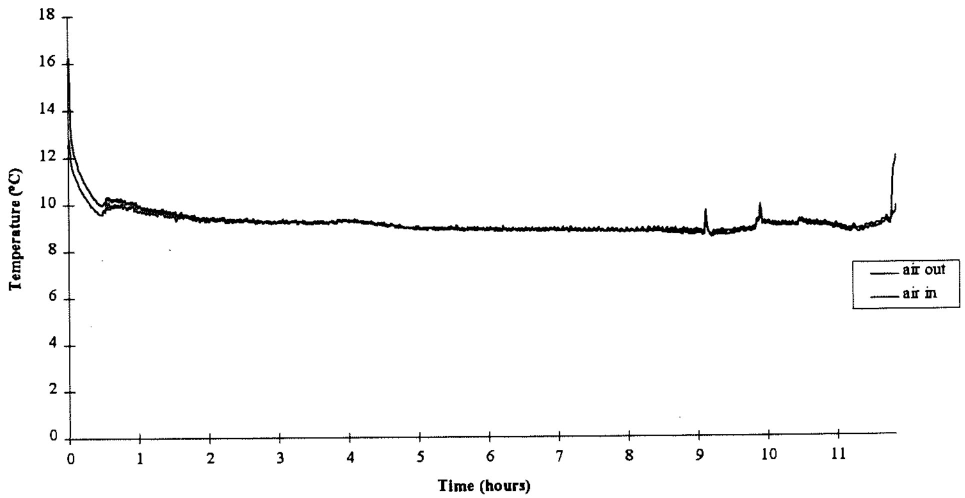


Figure 6.1

Temperatures during drying barramundi maw at 35°C

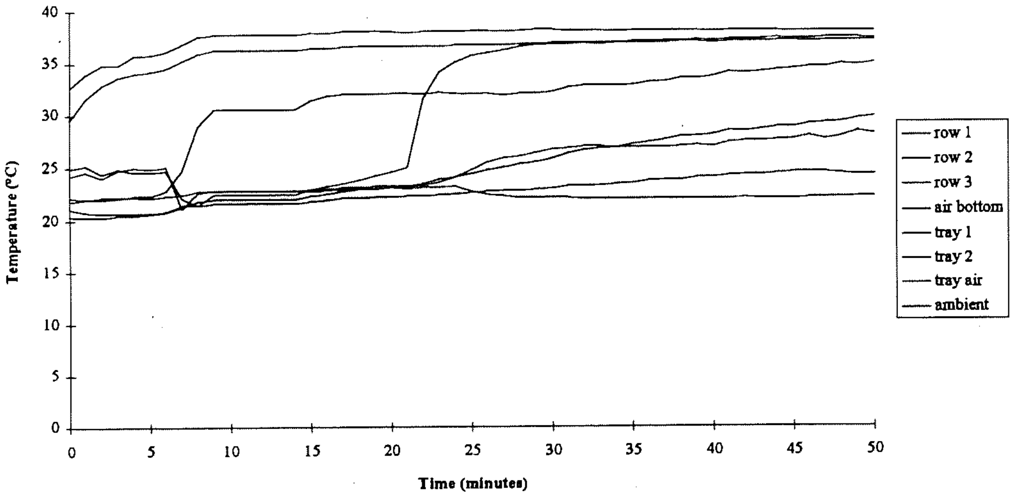


Figure 6.2

Weight changes during drying barramundi maw at 35°C

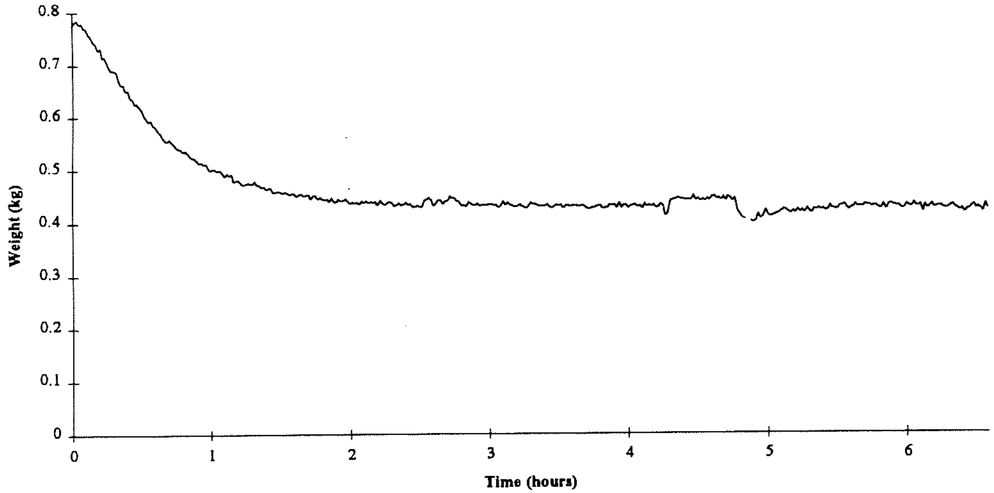


Figure 6.3

Humidity during drying barramundi maw at 35°C

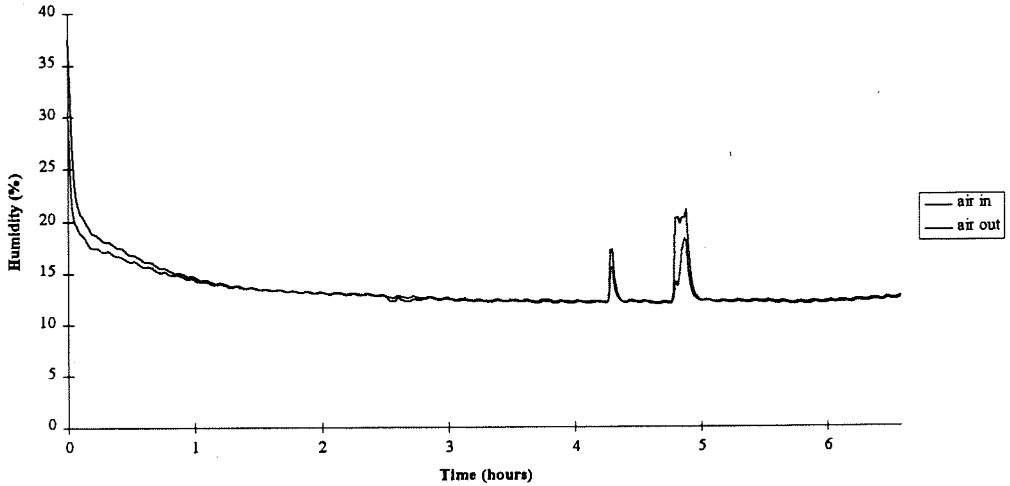


Figure 6.4

Temperatures during drying of sodium hypochlorite treated fish maw at 45°C

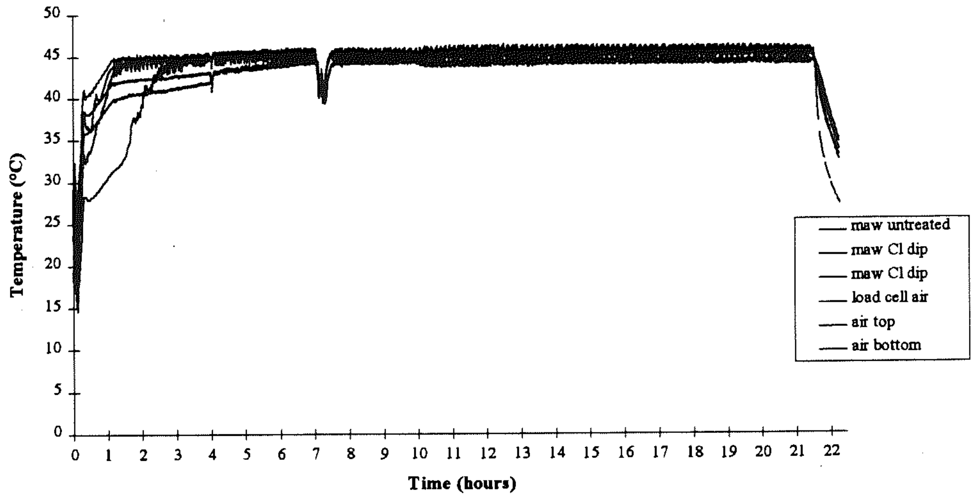


Figure 6.5

Weight changes during drying of sodium hypochlorite treated fish maw at 45°C

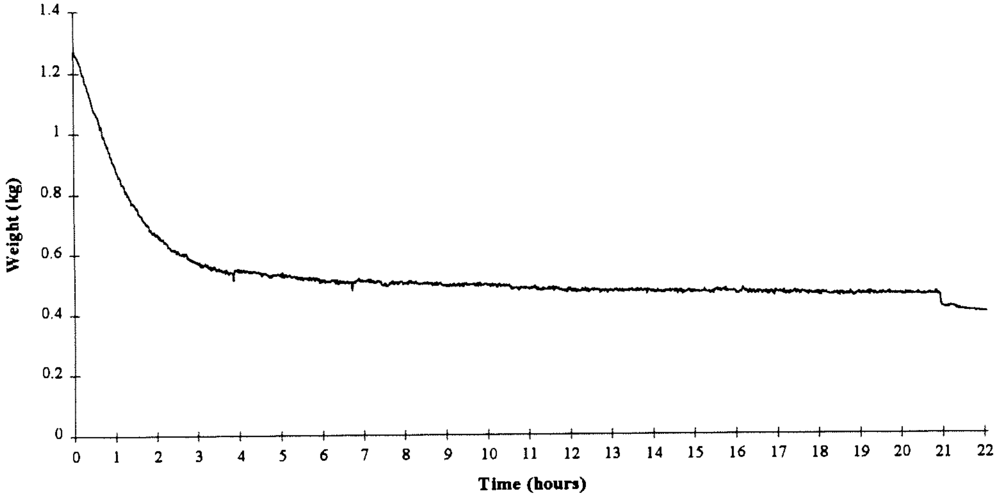


Figure 6.6

Humidity of air during drying of sodium hypochlorite treated fish maw at 45°C

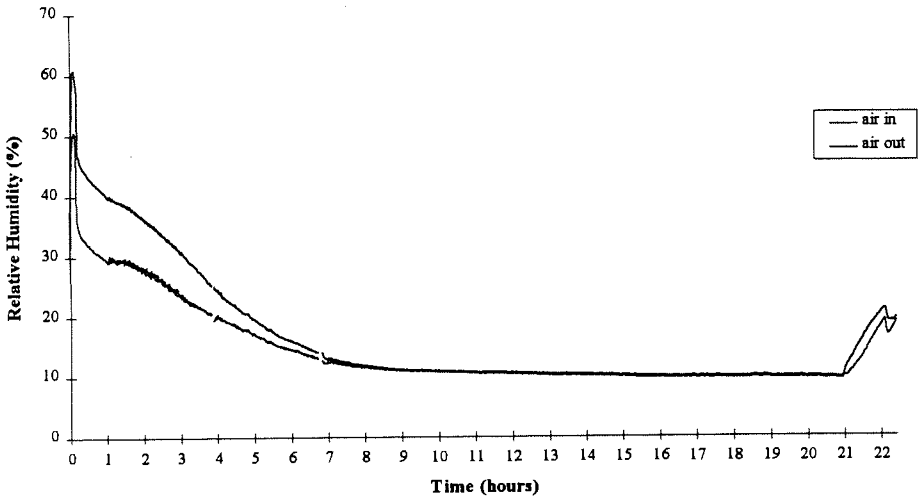


Figure 6.7

Initial temperatures during drying of hydrogen peroxide treated maw at 55°C

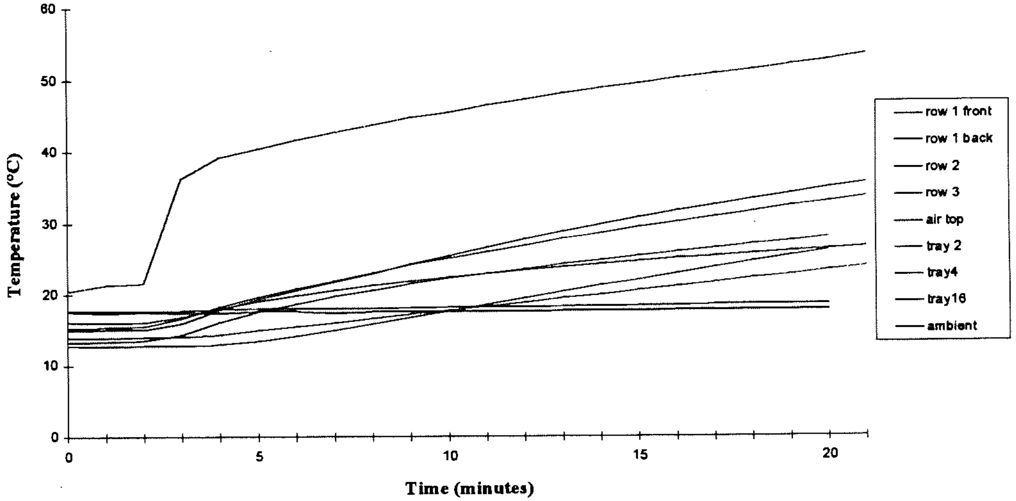


Figure 6.8

Weight changes during drying hydrogen peroxide treated maws at 55°C

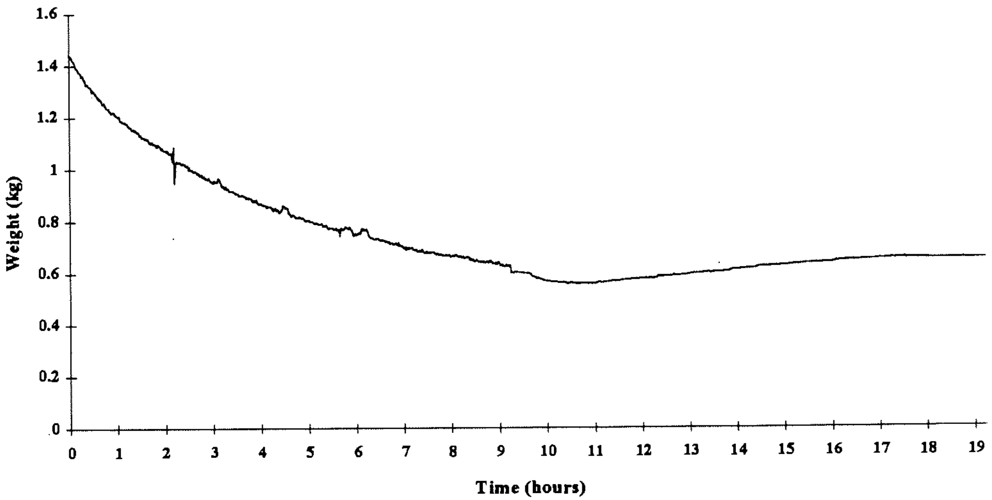


Figure 6.9

Humidity during drying hydrogen peroxide treated maws at 55°C

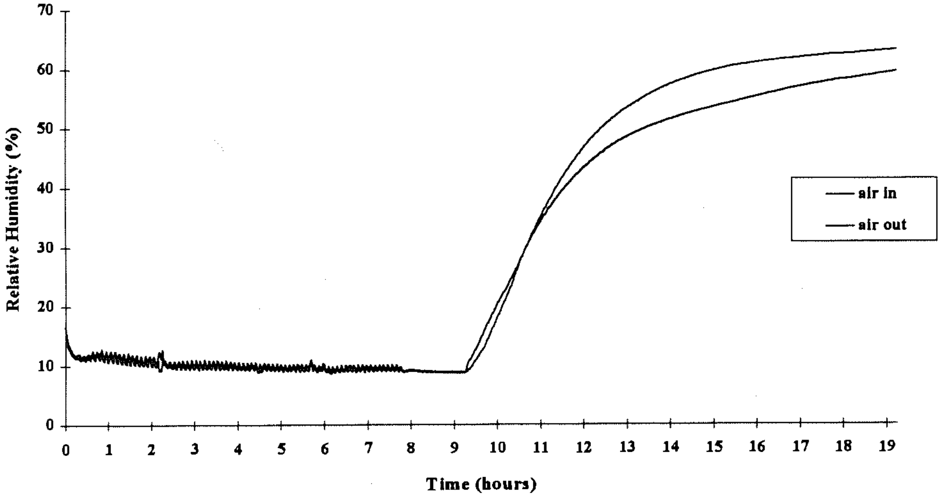


Figure 6.10

Temperatures during second drying of hydrogen peroxide treated maw at 35°C

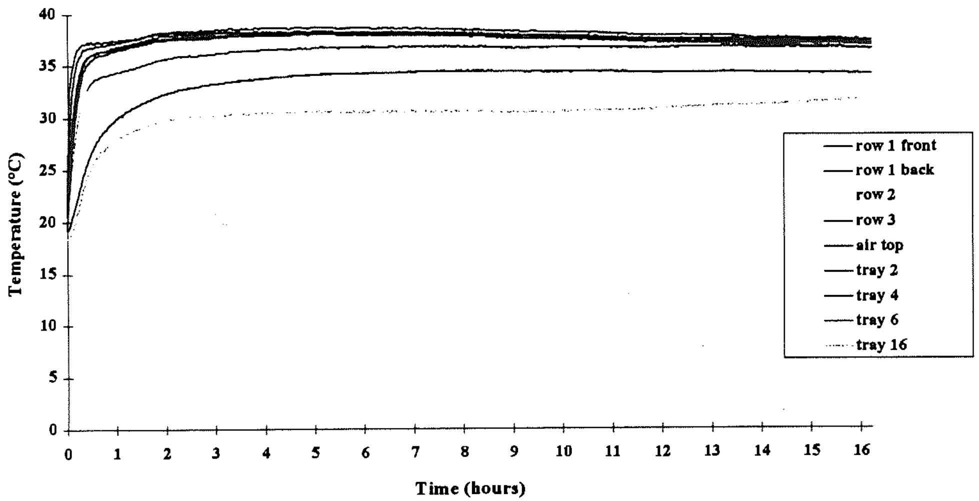


Figure 6.11

Weight changes during second drying of hydrogen peroxide treated maw at 35°C

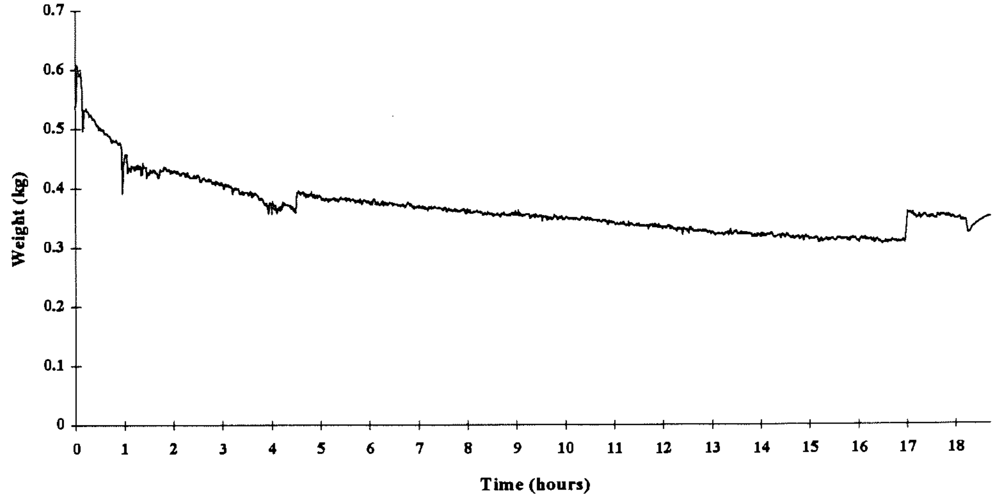


Figure 6.12

Humidity during second drying of hydrogen peroxide treated maw at 35°C

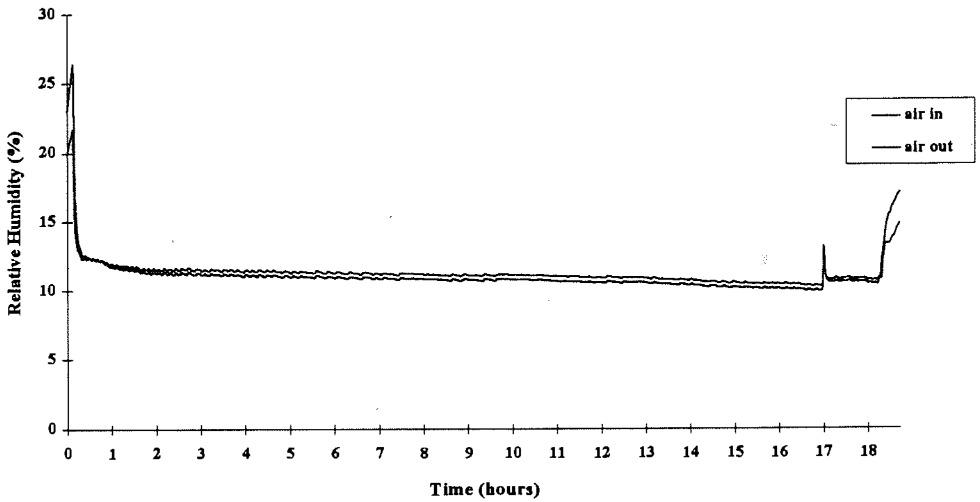


Figure 6.13

Temperatures during drying sodium hyperchlorite treated fish maw at 55°C

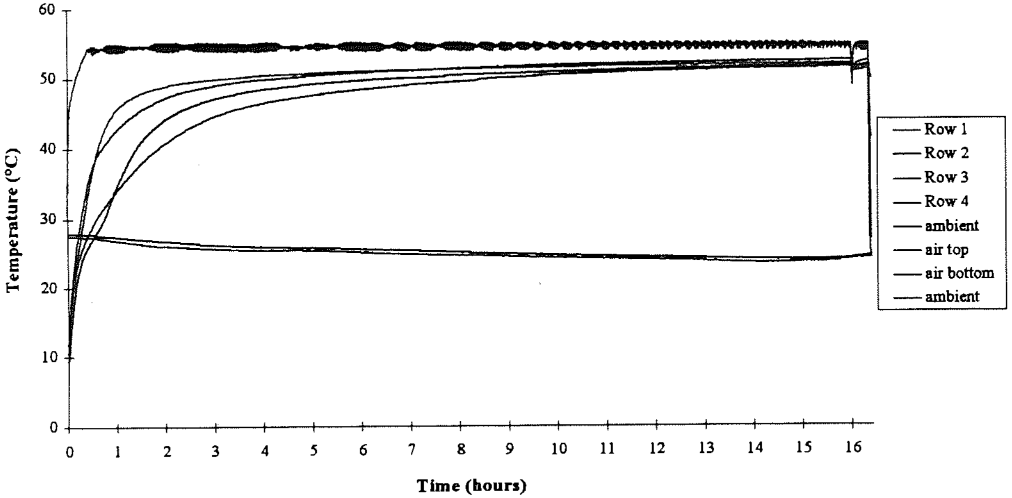


Figure 6.14

Weight changes during drying of sodium hyperchlorite treated fish maw at 55°C

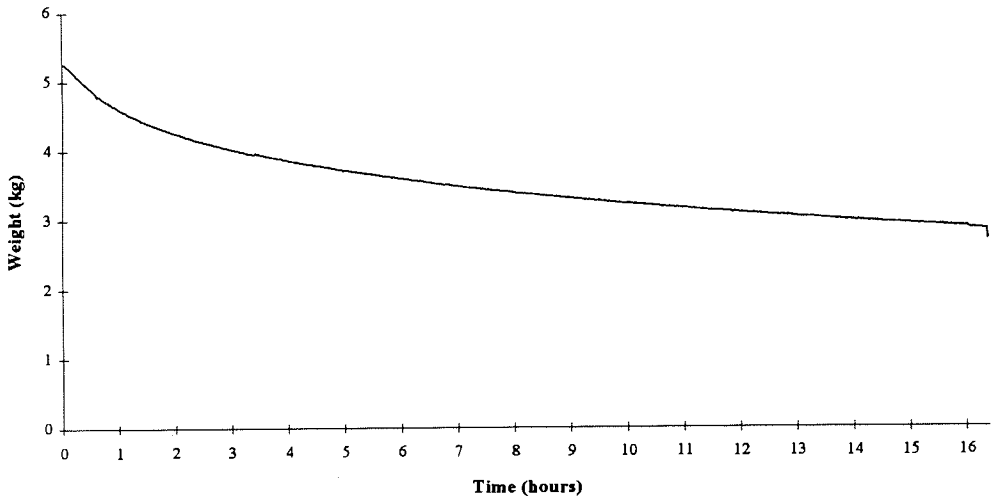


Figure 6.15

Humidity during drying of sodium hyperchlorite treated fish maw at 55°C

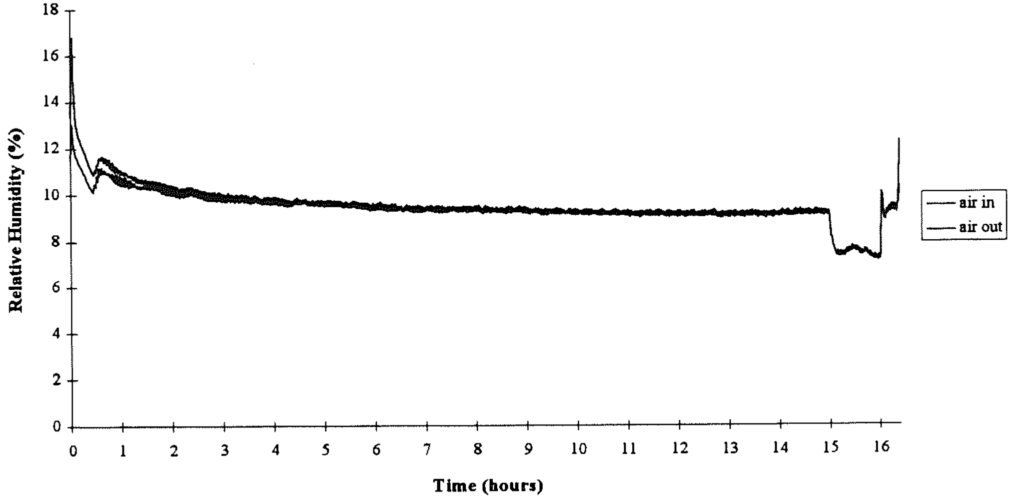


Figure 6.16

Temperatures during second drying of sodium hyperchlorite treated fish maw at 35°C

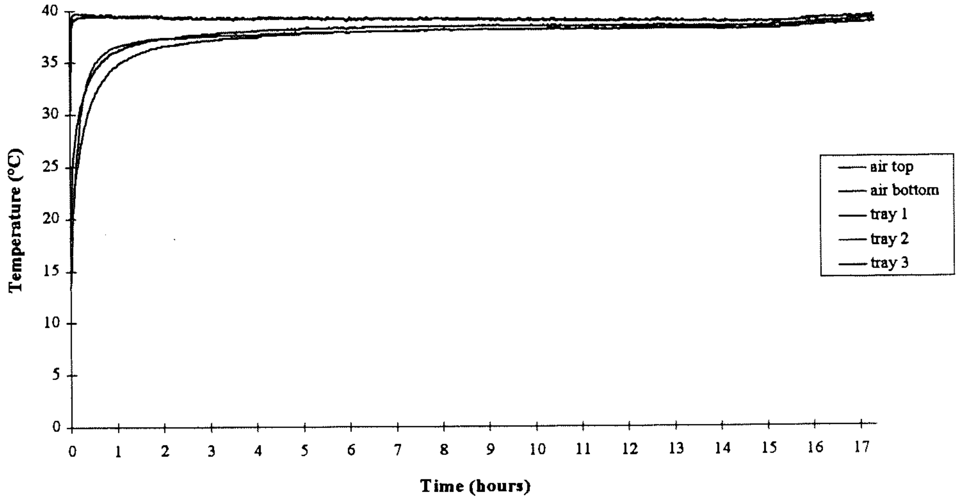


Figure 6.17

Humidity during second drying of sodium hyperchlorite treated fish maw (initially dried at 55°C) at 35°C

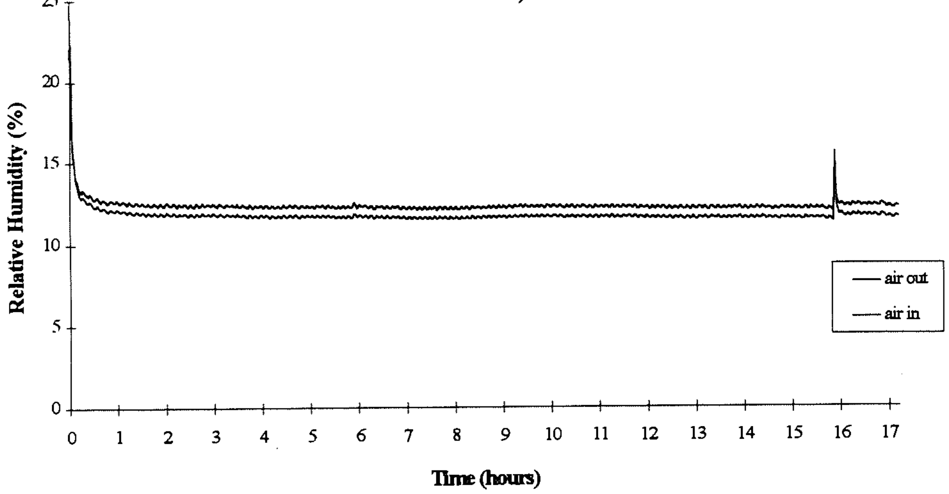


Figure 6.18

Temperatures during drying of sodium hyperchlorite treated fish maw at 35°C

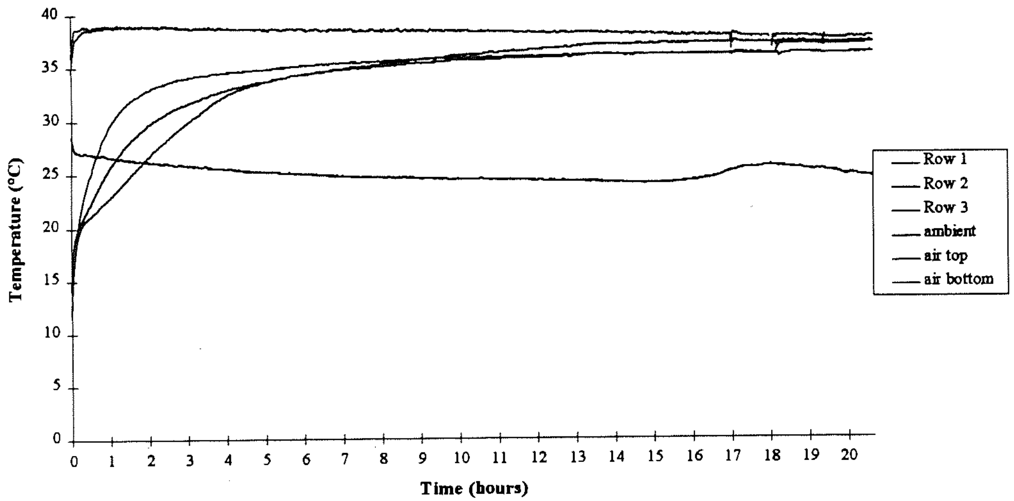


Figure 6.19

Weight changes during drying of sodium hyperchlorite treated fish maw at 35°C

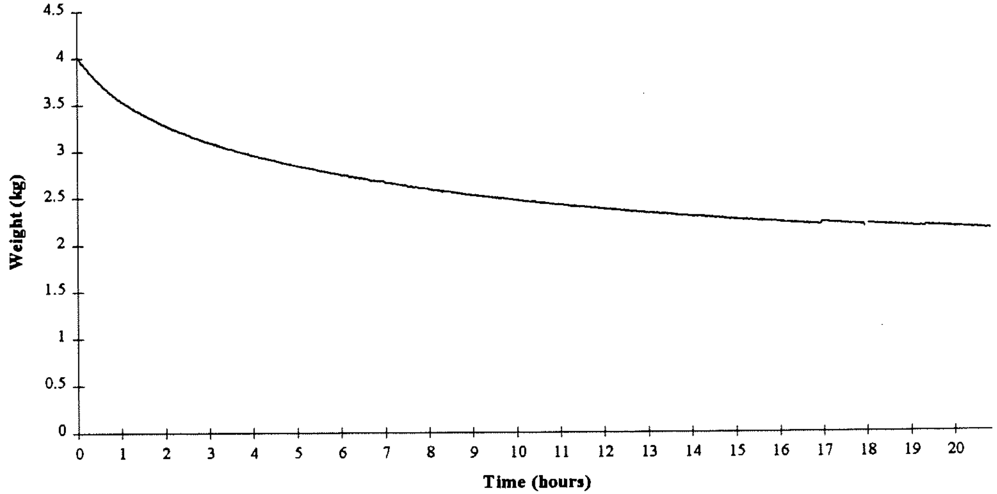


Figure 6.20

Humidity during drying of sodium hyperchlorite treated fish maw at 35°C

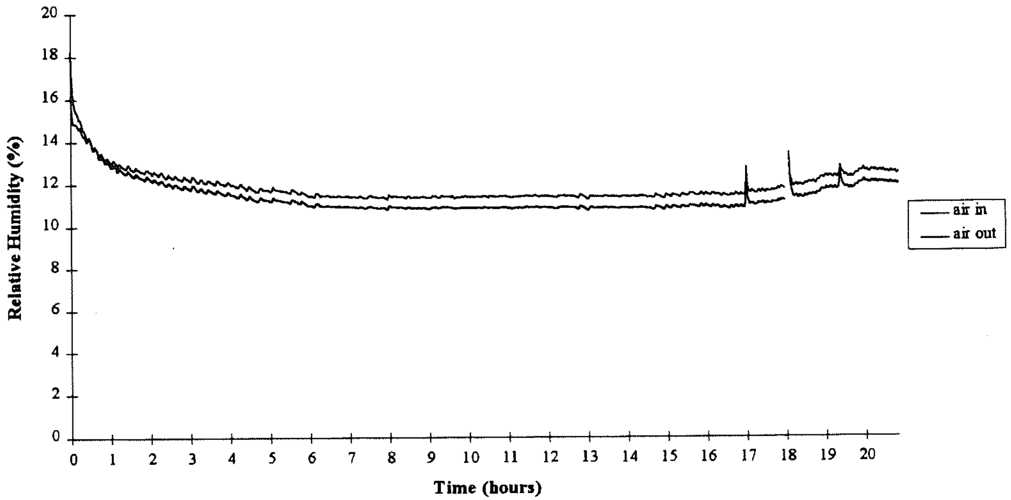


Figure 6.21

Temperatures during second drying of sodium hyperchlorite treated fish maw (initially dried at 35°) at 35°C

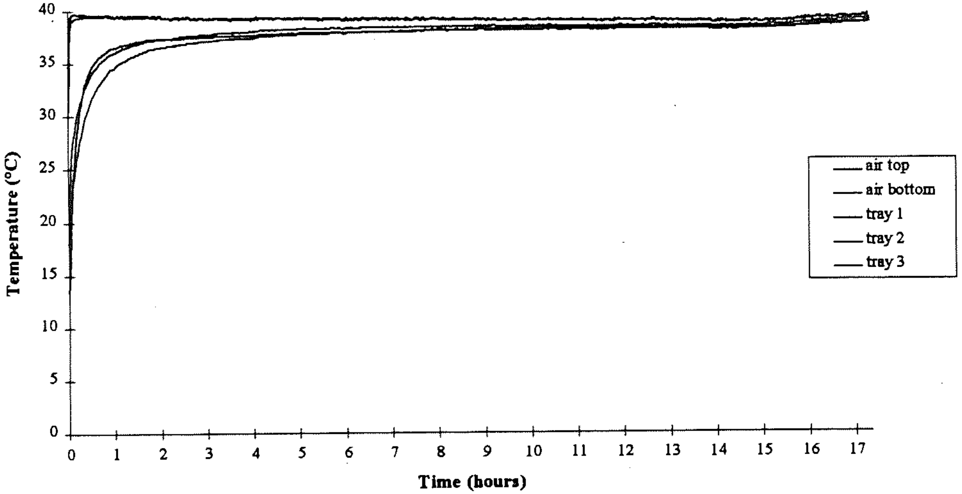


Figure 6.22

Weight changes during second drying of sodium hyperchlorite treated fish maw (initially dried at 35°C) at 35°C

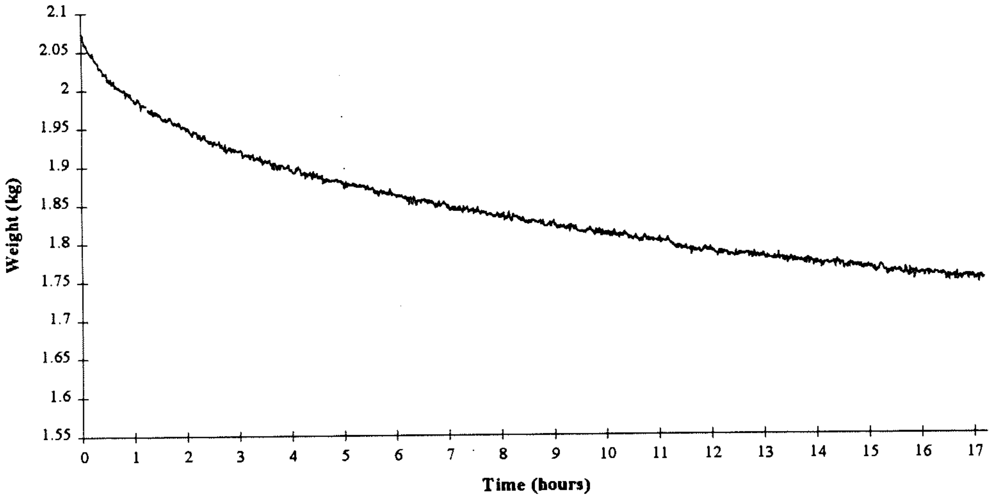


Figure 6.23

Humidity during second drying of sodium hyperchlorite treated fish maw at 35°C

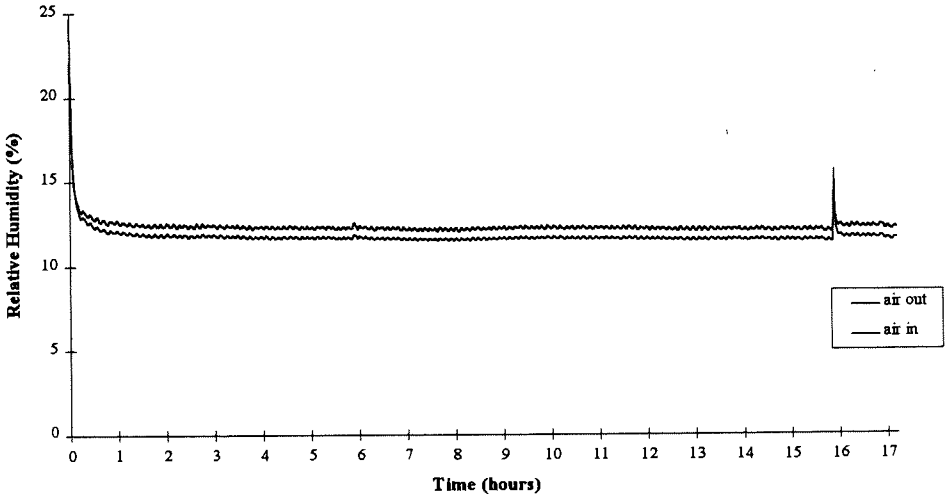


Figure 6.24

Temperatures during drying sodium hyperchlorite and sodium hydroxide treated fish maw at 35°C

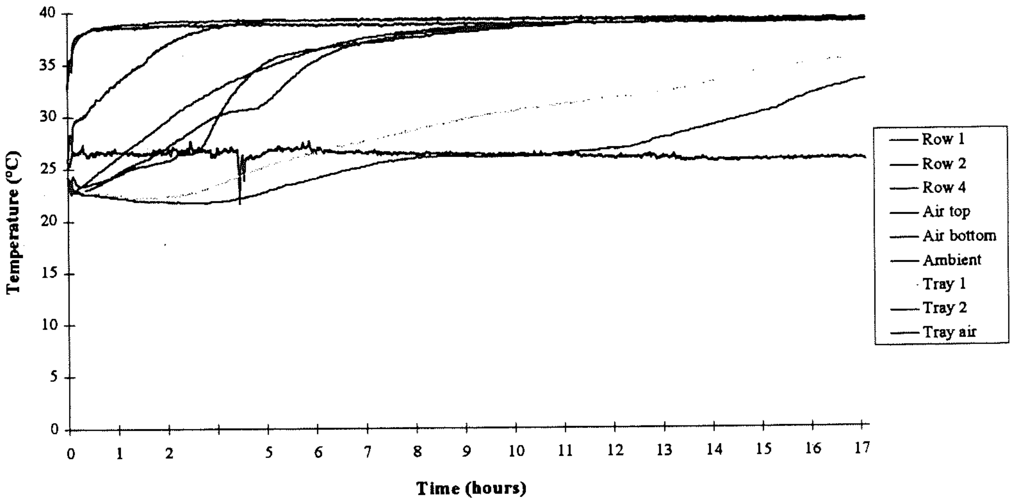


Figure 6.25

Weight changes during drying manually cleaned, sodium hyperchlorite only treated fish maw at 35°C

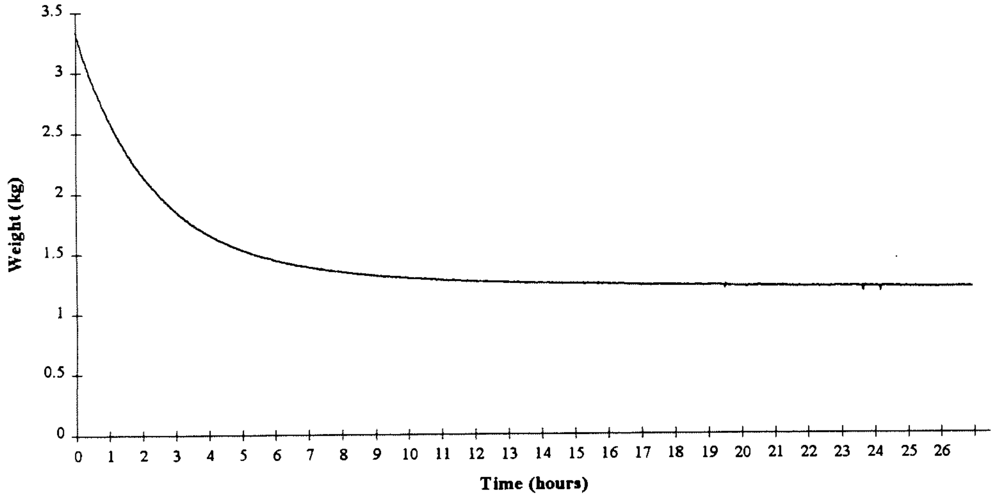


Figure 6.27

Temperatures during intermittent drying of sodium hydroxide dipped fish maw at 35°C

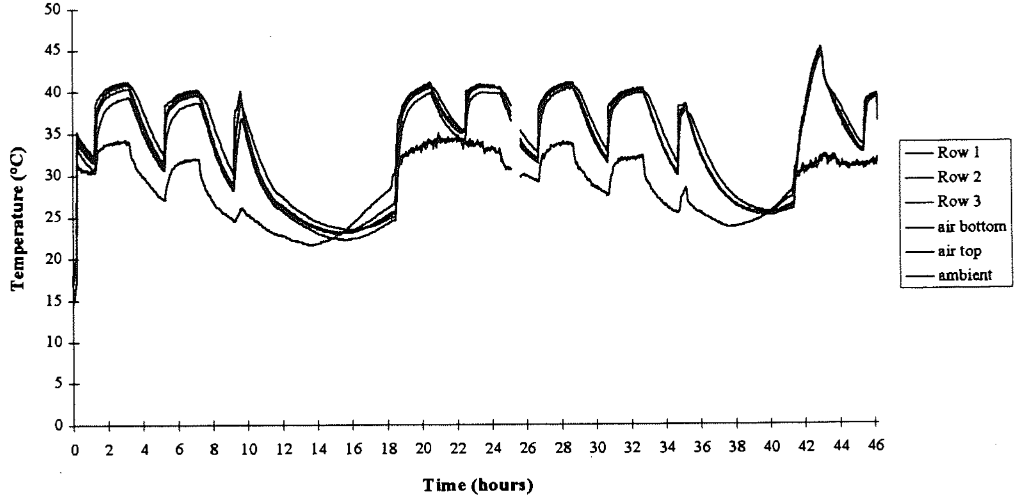


Figure 6.26

Humidity during drying sodium hyperchlorite and sodium hydroxide treated fish maw at 35°C

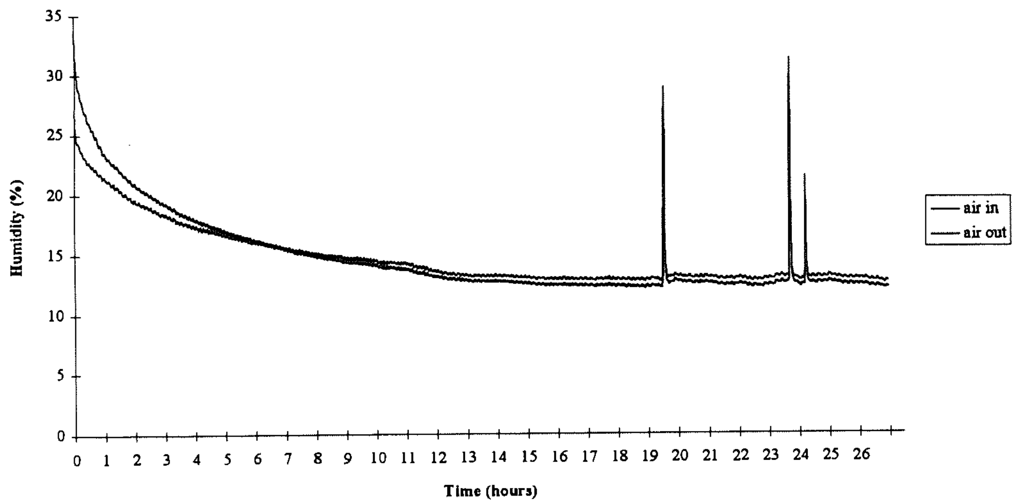


Figure 6.28

Weight changes during intermittent drying of sodium hydroxide dipped fish maw at 35°C

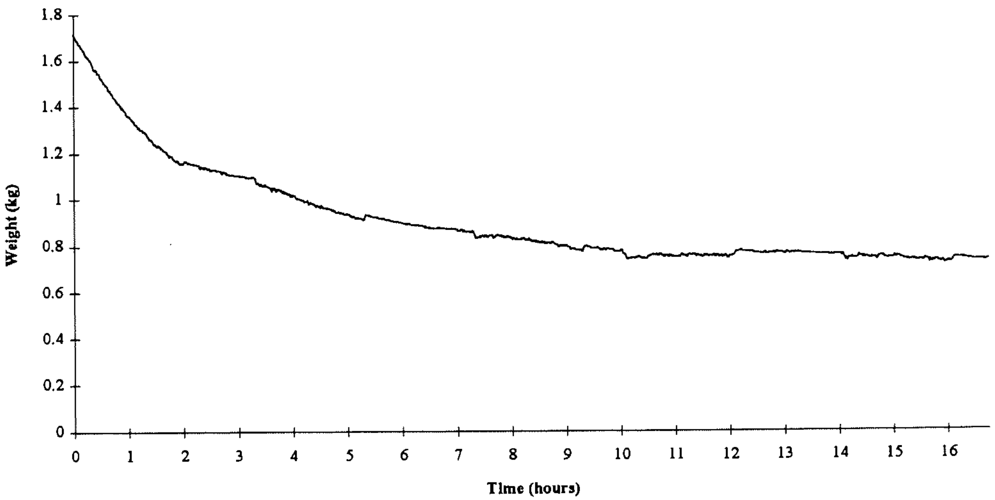


Figure 6.29

Humidity during intermittent drying of sodium hydroxide dipped fish maw at 35°C

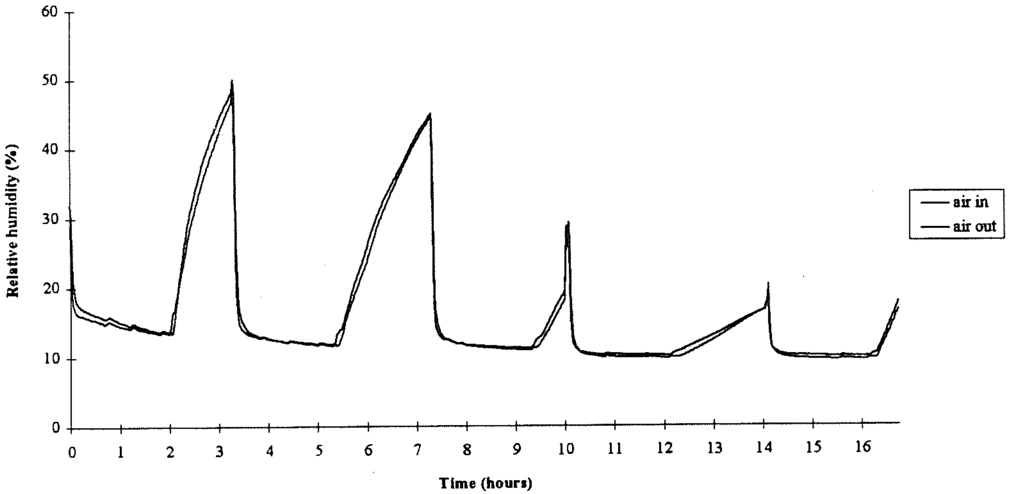


Figure 6.31

Weight changes during drying of maws sodium hydroxide and sodium metabisulphite treated fish maw at 35°C

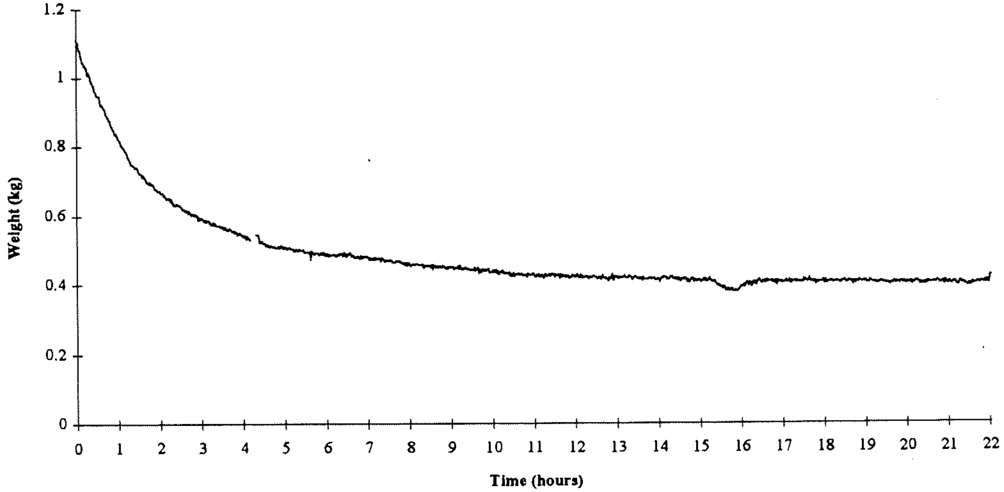


Figure 6.30

Temperatures during drying of sodium hydroxide and sodium metabisulphite treated fish maw at 35°C

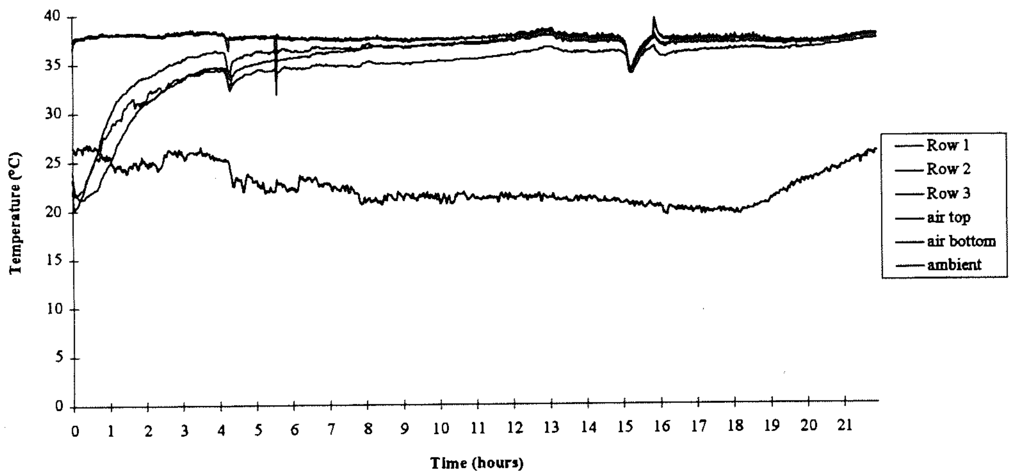


Figure 6.32

Humidity during drying of sodium hydroxide and sodium metabisulphite treated fish maw at 35°C

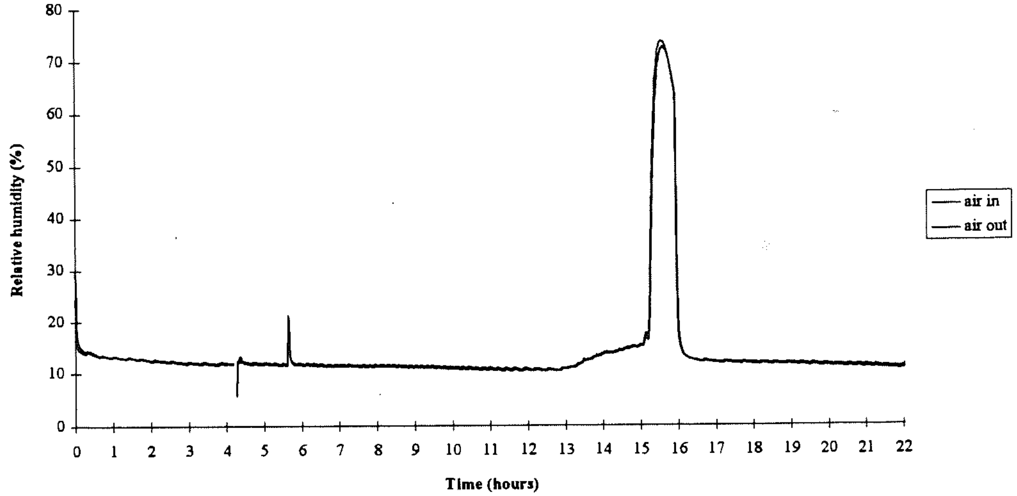


Figure 6.33

Temperatures during drying potassium sorbate treated fish maw at 35°C

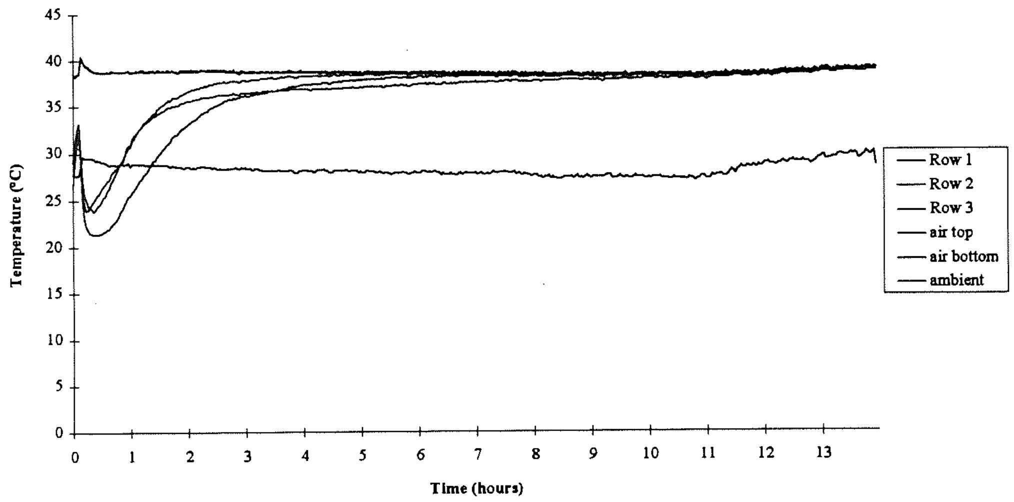


Figure 6.34

Weight changes during drying potassium sorbate treated fish maw at 35°C

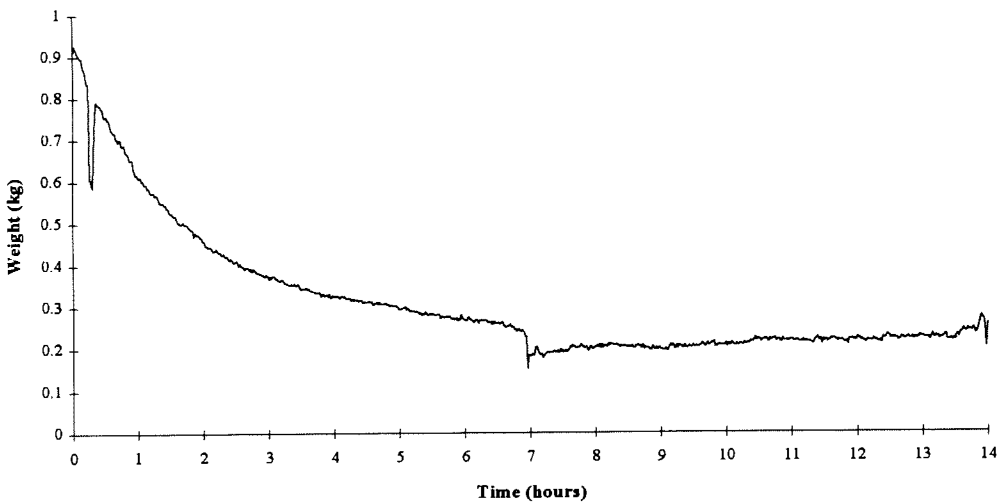


Figure 6.35

Humidity during drying potassium sorbate treated fish maw at 35°C

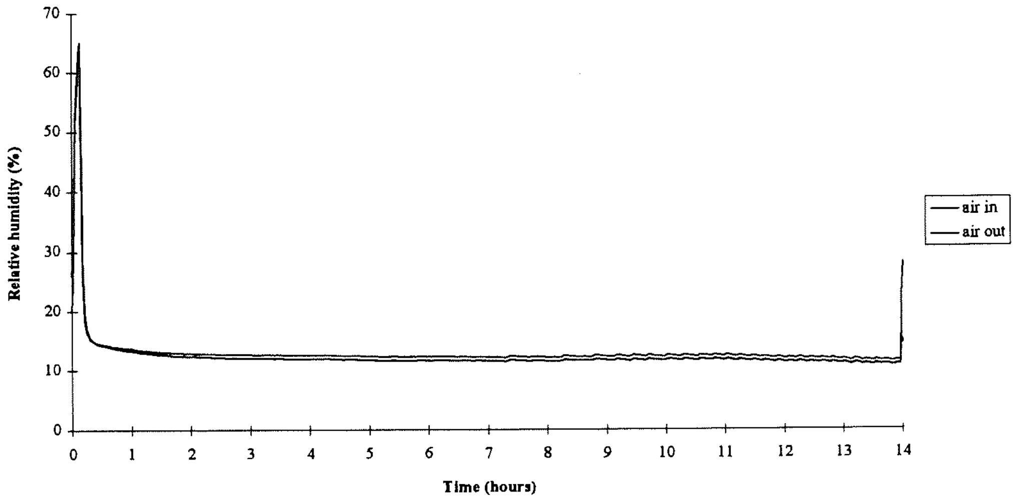


Figure 6.36

Temperatures during drying jew fish maw at 35°C

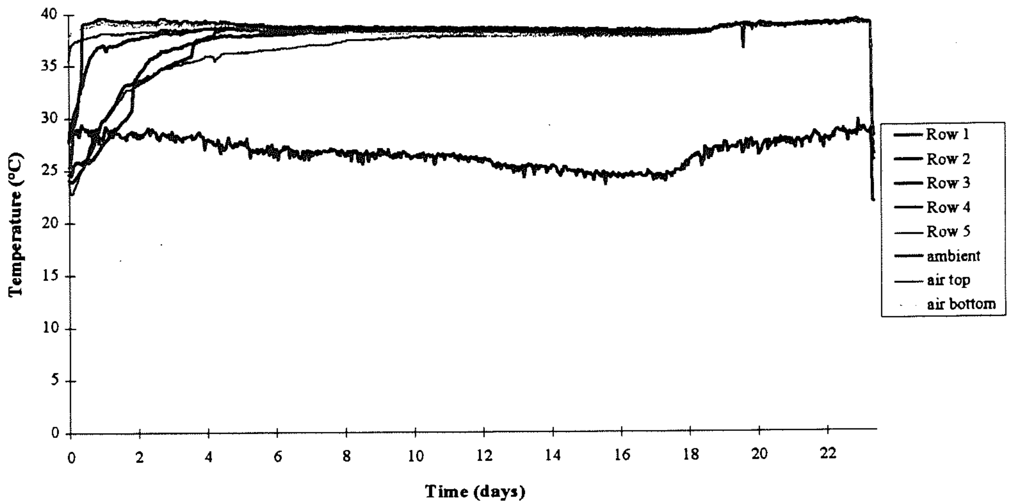


Figure 6.37

Weight changes during drying of jew fish maw at 35°C

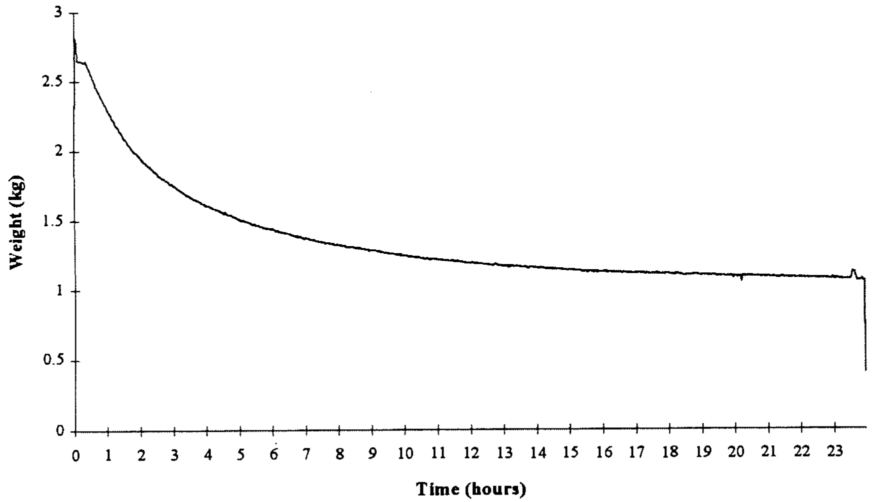


Figure 6.38

Humidity during drying of jew fish maw at 35°C

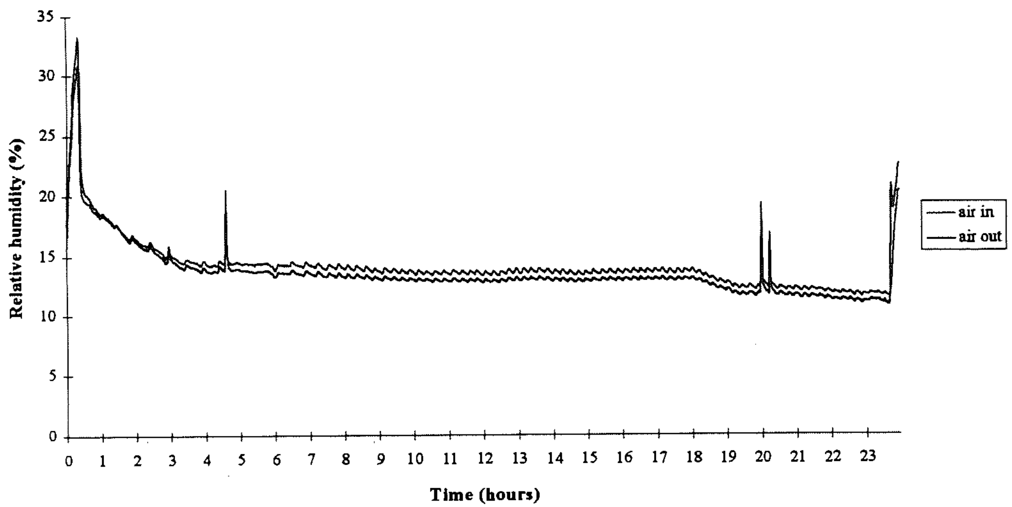


Figure 6.39

Temperatures during second drying of jew fish maw at 35°C

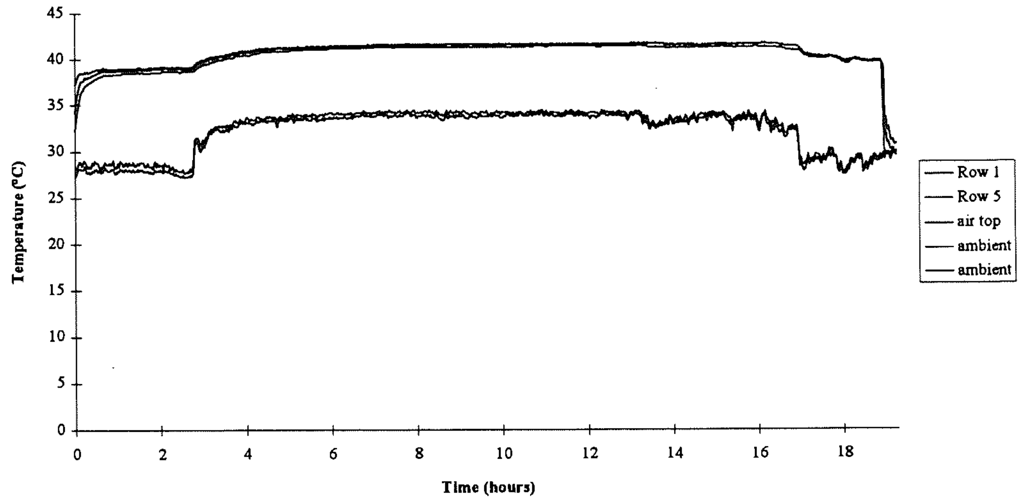


Figure 6.40

Weight changes during the second drying of jew fish maw at 35°C

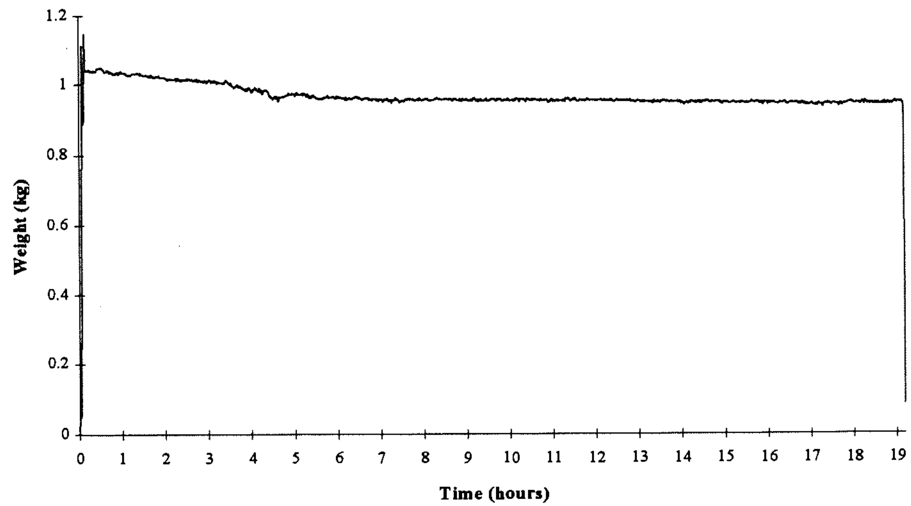


Figure 6.41

Humidity during the second drying of jew fish maw at 35°C

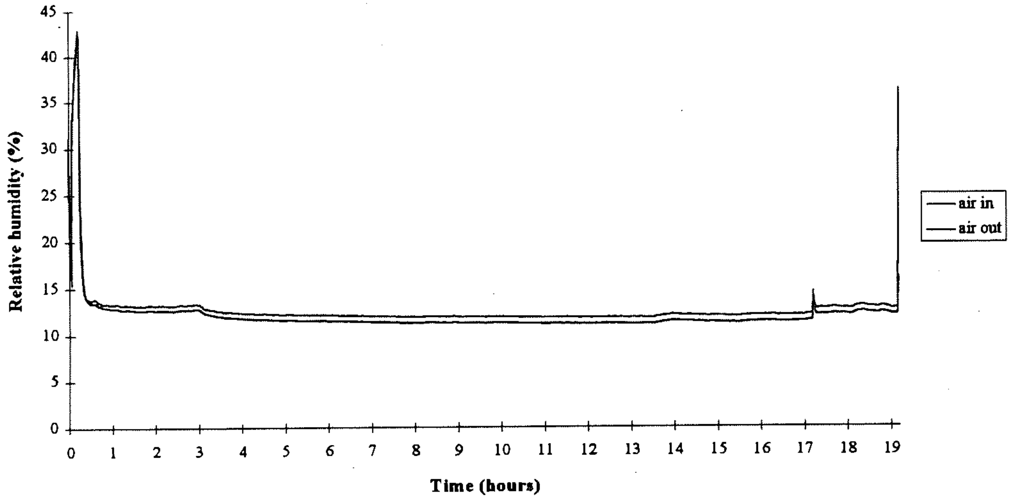


Figure 7.1

Temperatures during drying shark fillets at 35°C

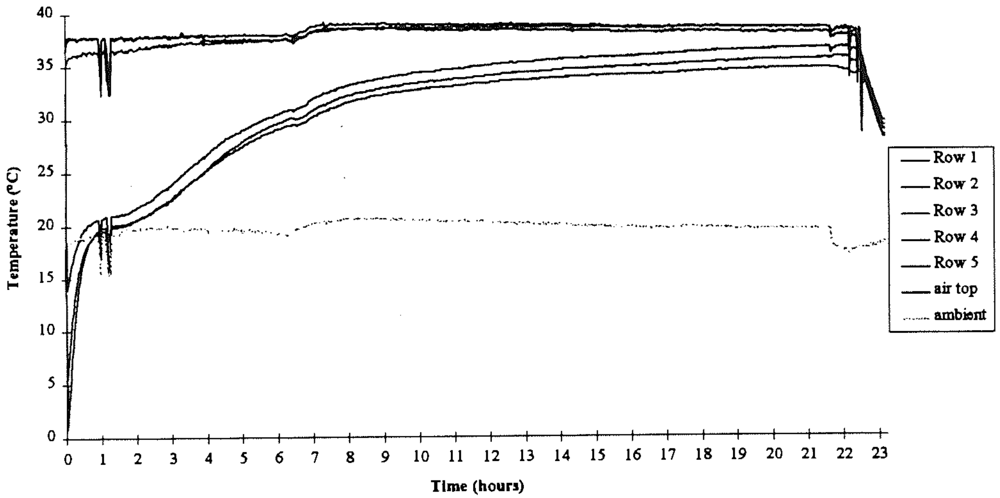


Figure 7.2

Weight changes during drying shark fillets at 35°C

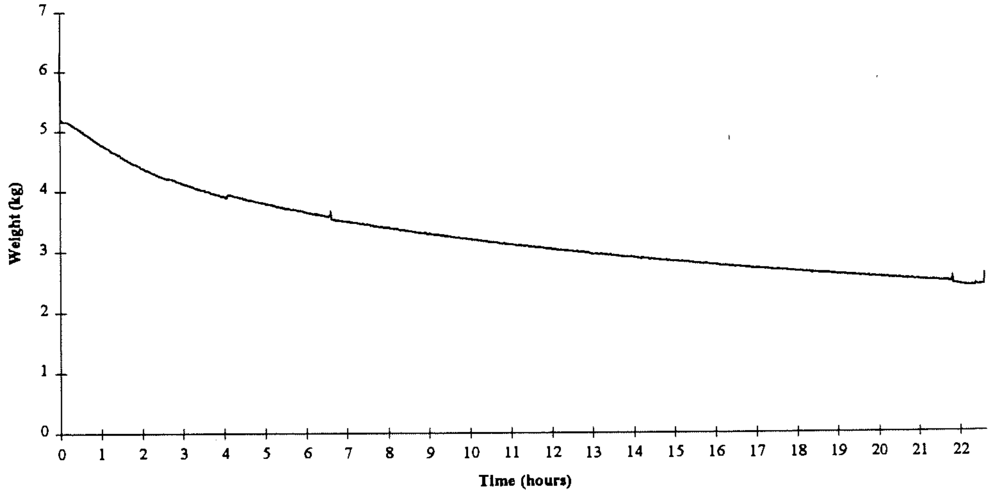


Figure 7.3

Humidity during drying shark fillets at 35°C

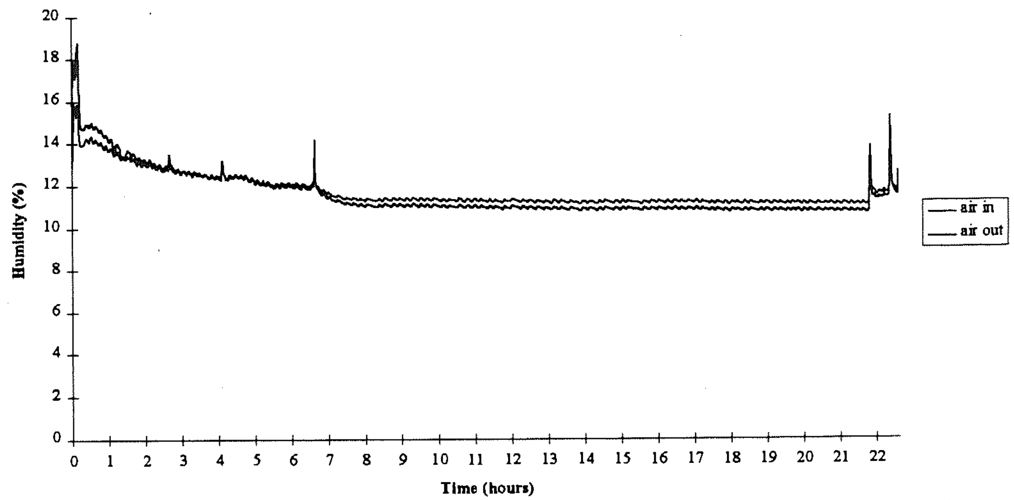


Figure 7.4

Temperatures during second drying of shark fillet at 35°C

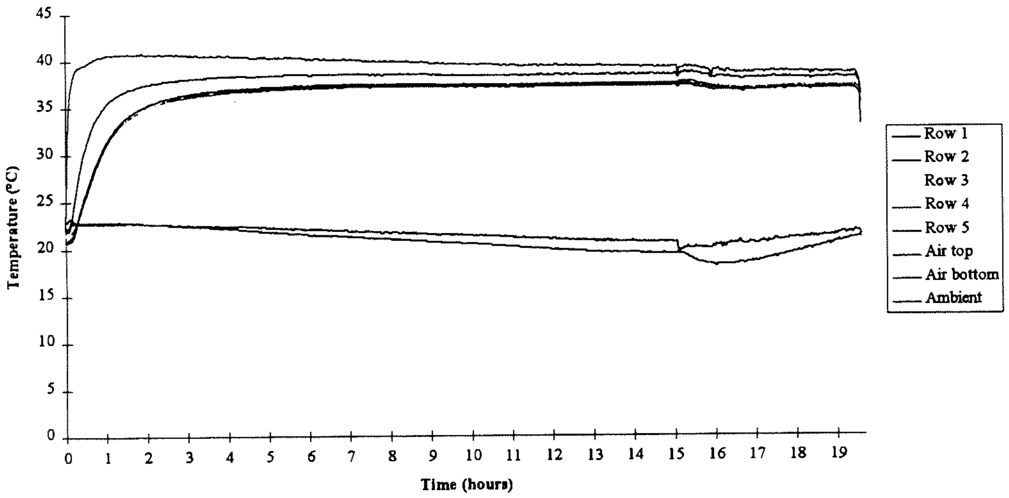


Figure 7.5

Weight changes during second drying of shark fillets at 35°C

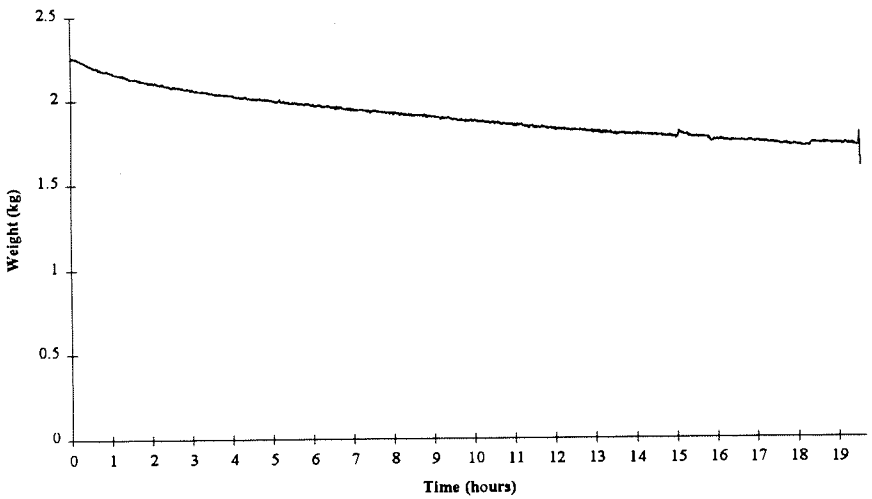


Figure 7.6

Humidity during second drying of shark fillets at 35°C

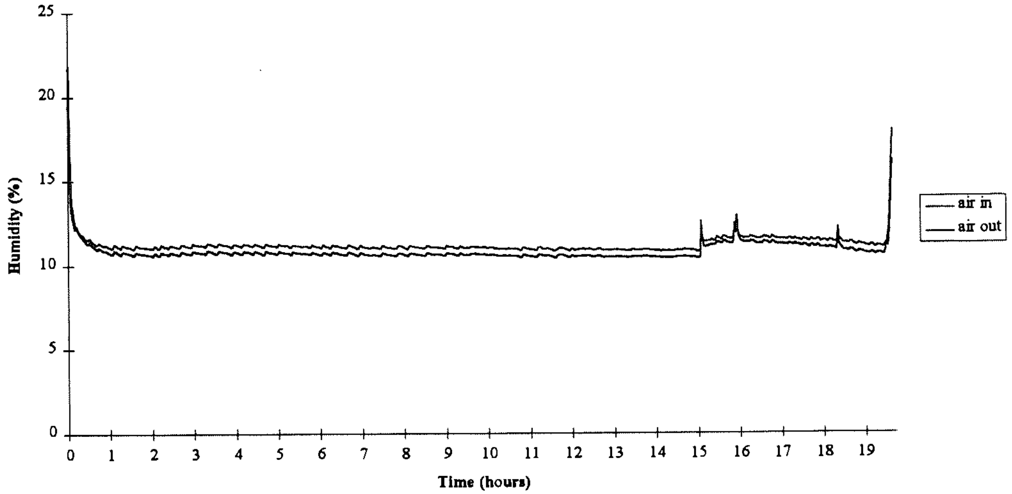


Figure 7.7

Temperatures during drying salted shark fillet at 35°C

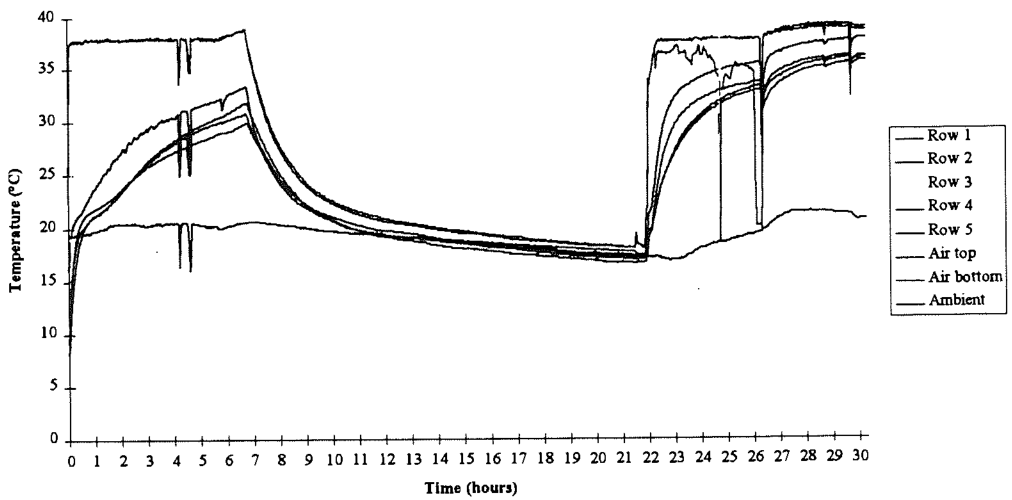


Figure 7.8

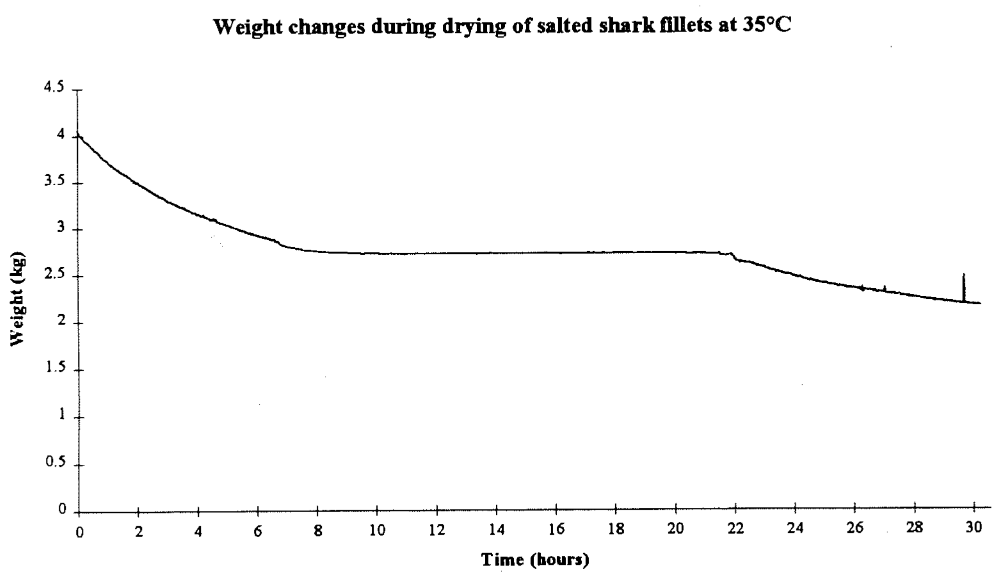


Figure 7.9

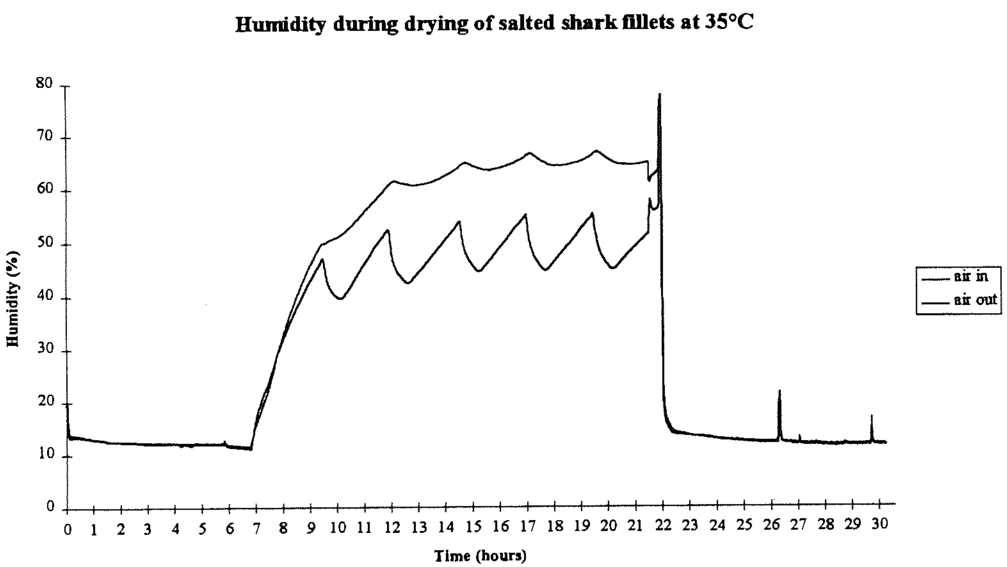


Figure 7.10

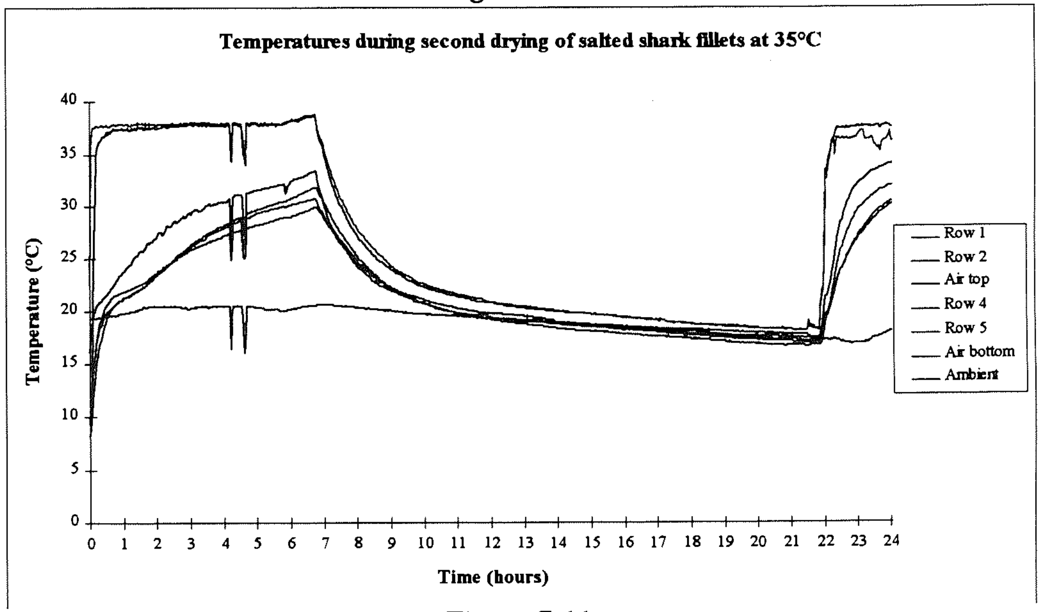


Figure 7.11

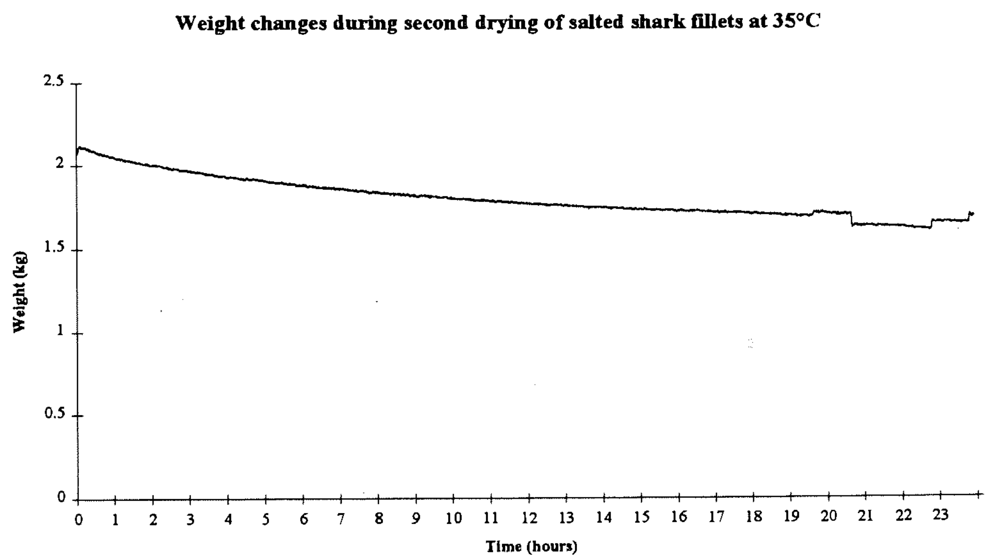


Figure 7.12

Humidity during second drying of salted shark fillets at 35°C

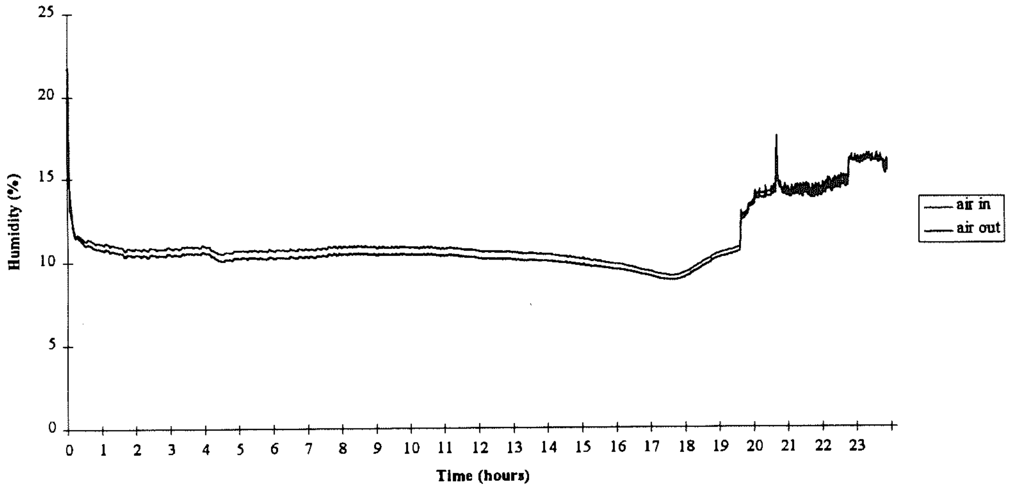


Figure 7.13

Temperature during drying of shark jerky at 55°C

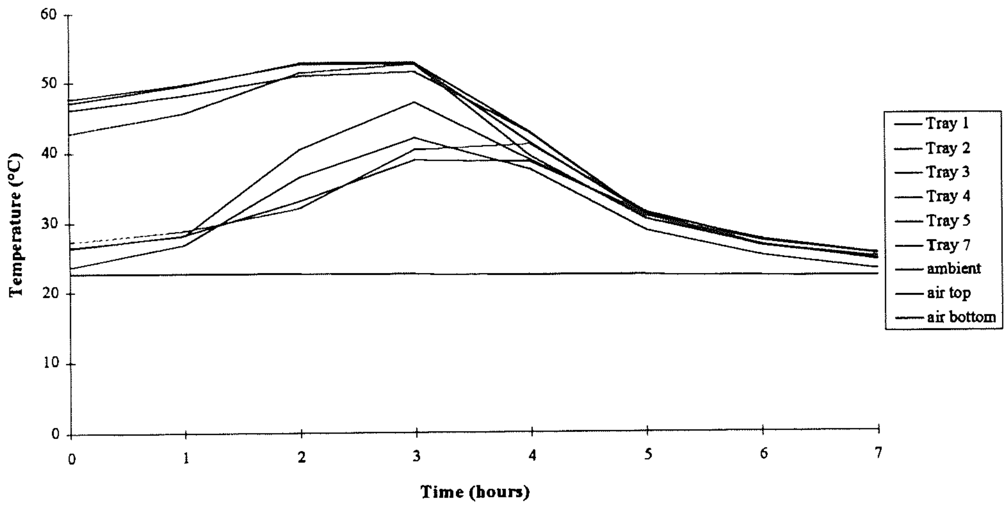


Figure 7.14

Weight change during drying of shark jerky at 55°C

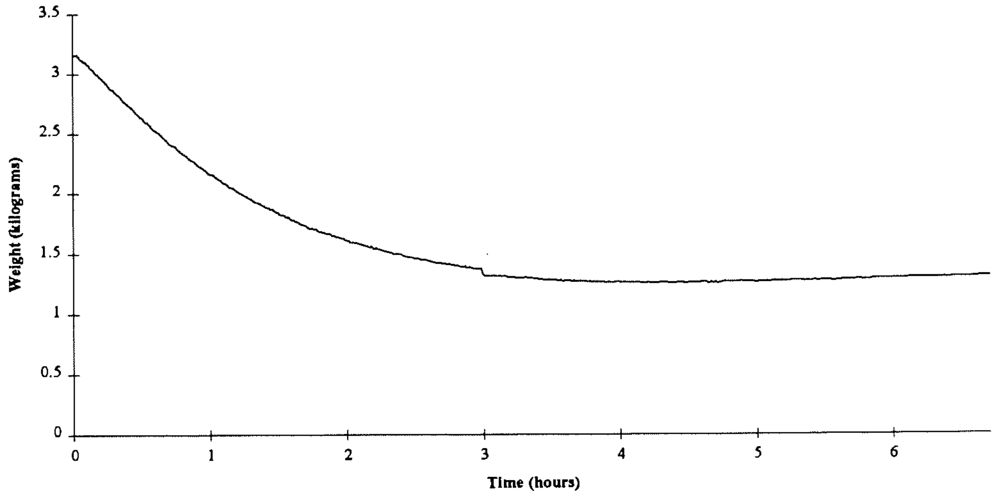
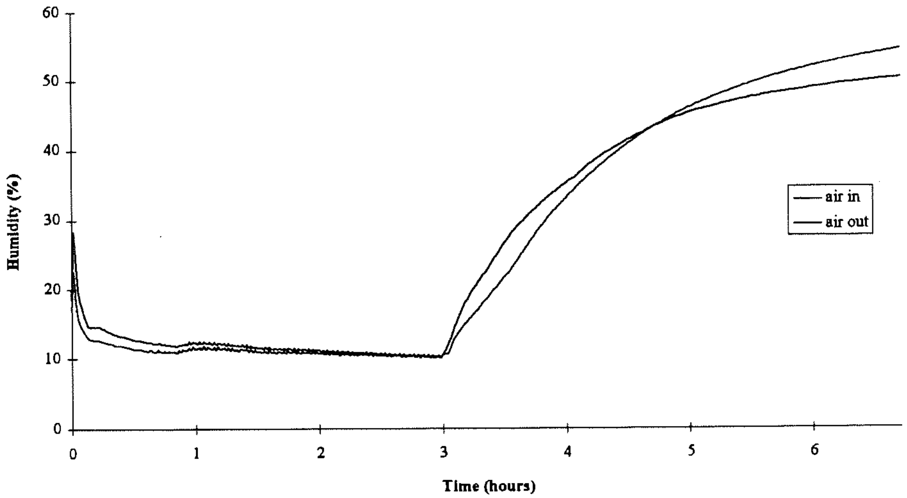


Figure 7.15

Humdity during drying shark jerky at 55°C



APPENDIX 2 ECHINODERMS

Figure 8.1

Whole beche de mer weights during drying at 50°C

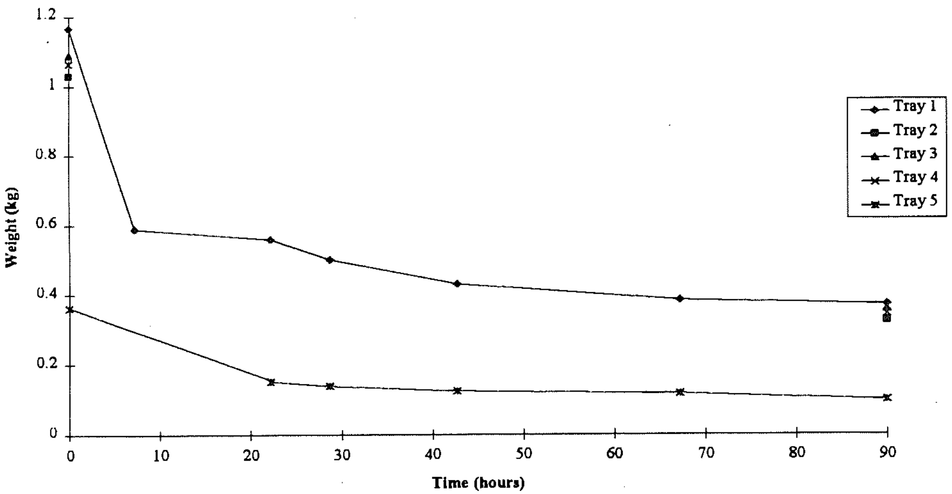


Figure 8.2

Temperatures of beche de mer strips from batch 1 during drying at 45°C

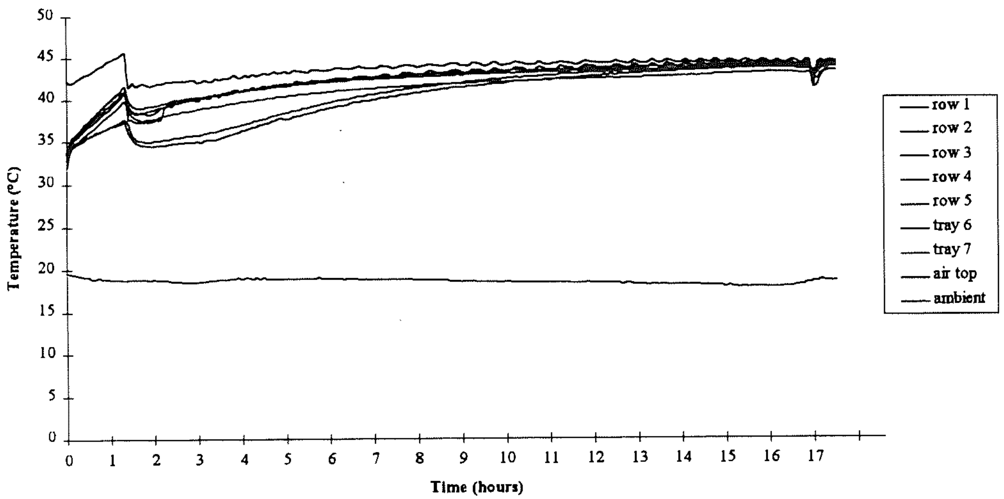


Figure 8.3

Weight changes during drying of beche de mer strips at 45°C for batch 1

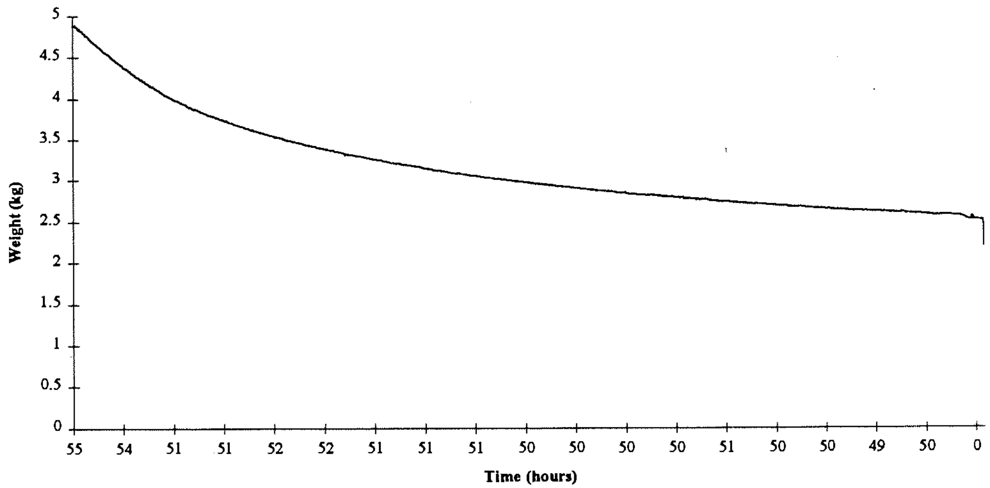


Figure 8.4

Humidity of air during drying of beche de mer strips at 45°C for batch 1

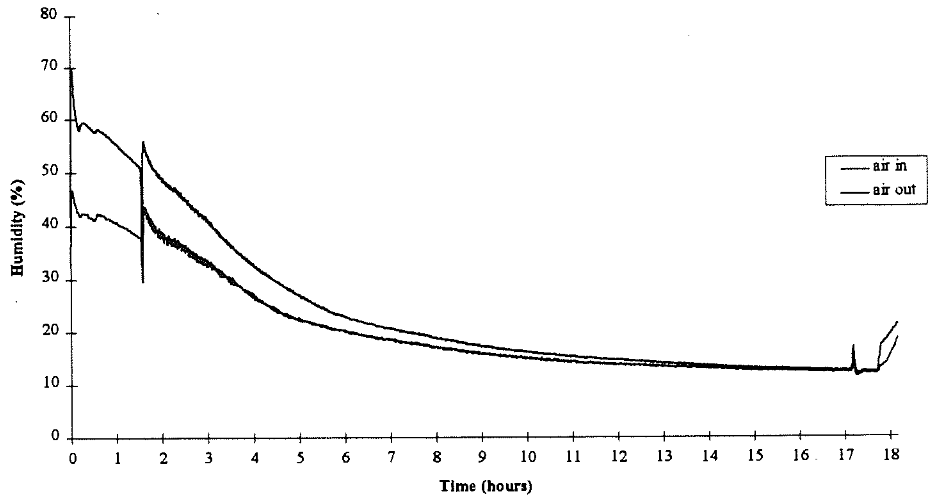


Figure 8.5

Temperature during drying of beche de mer strips at 45°C for batch two

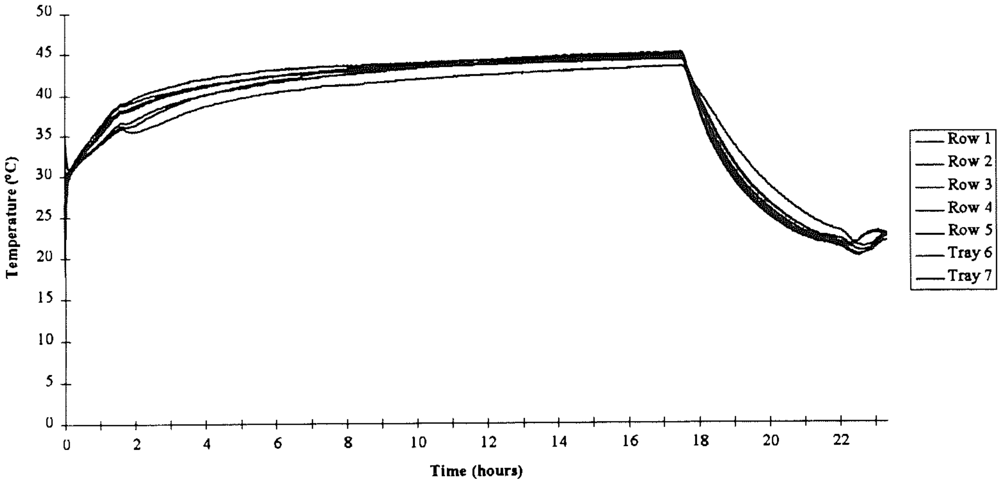


Figure 8.6

Weight changes during drying of beche de mer strips at 45°C for batch 2

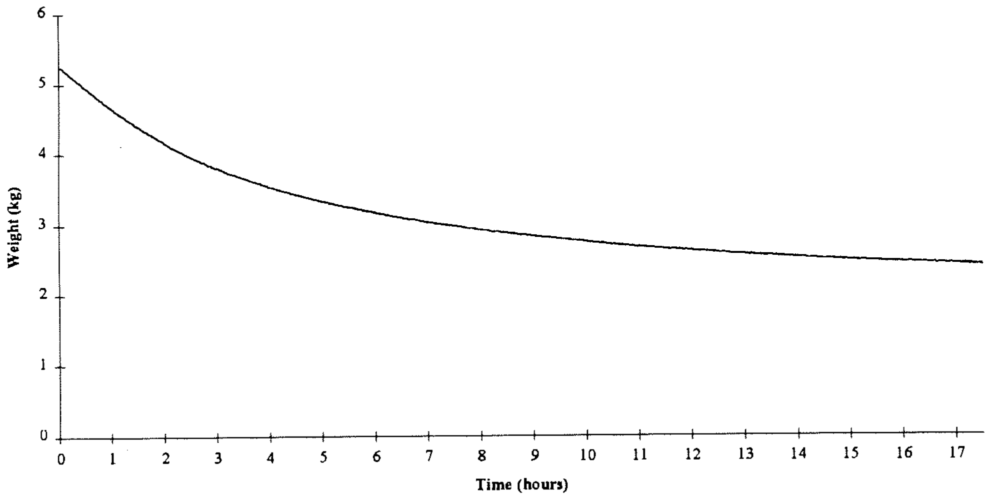


Figure 8.7

Humidity of air during drying of beche de mer strips at 45°C for batch 2

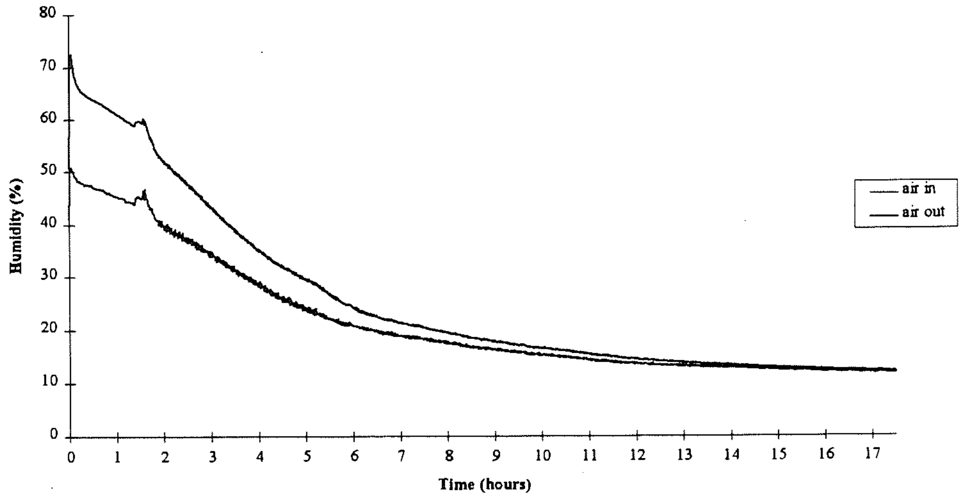


Figure 8.8

Temperatures during second drying of beche de mer strips at 55°C

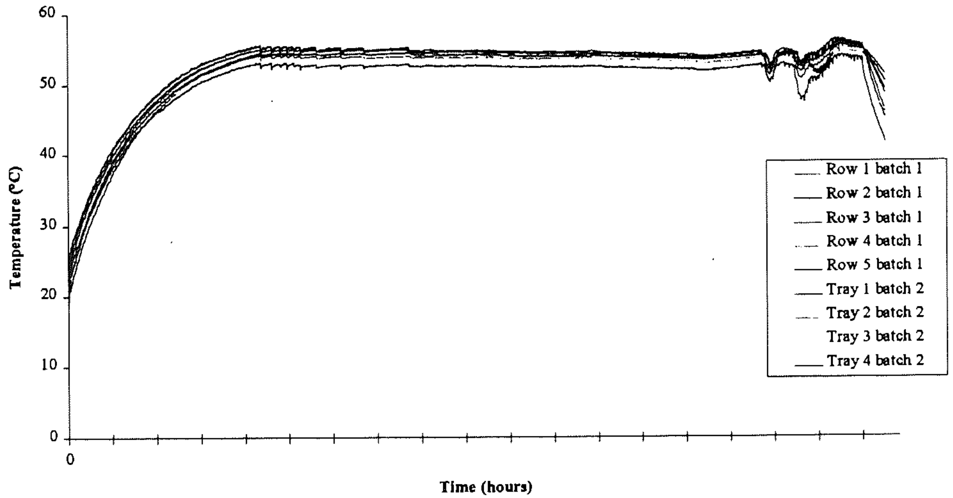


Figure 8.9

Weight changes during second drying of beche der mer strips at 55°C

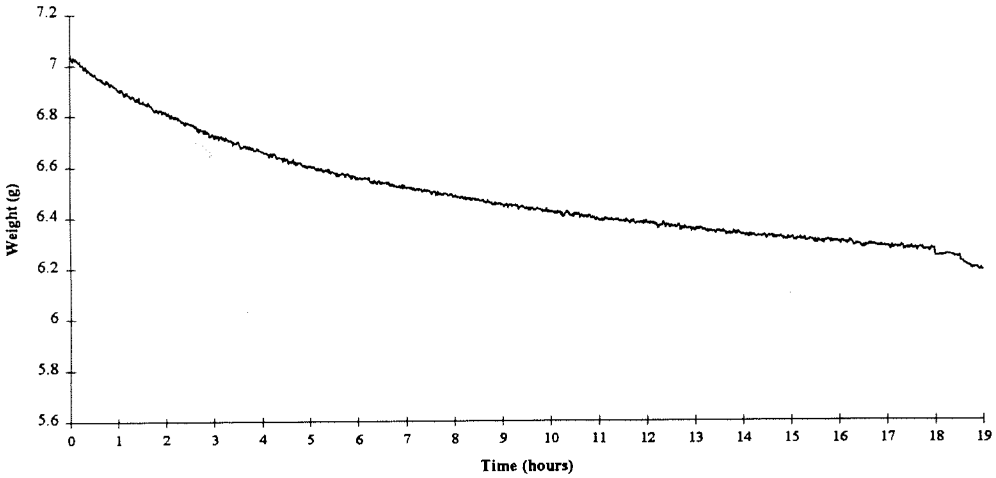
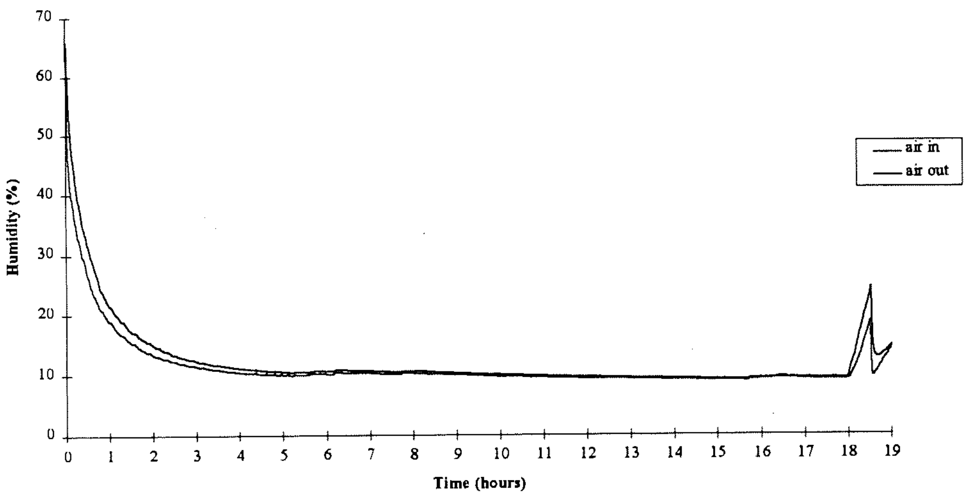


Figure 8.10

Humidity of air during second drying of beche de mer strips at 55°C



APPENDIX 3 MOLLUSCS

Figure 9.1

Temperature during drying of cuttlefish at 45°C

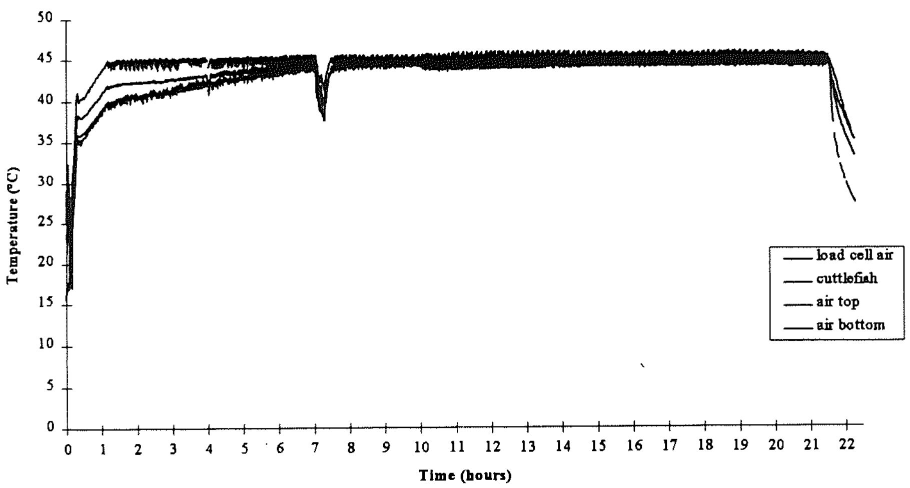


Figure 9.2

Temperatures during drying of cuttlefish at 35°C

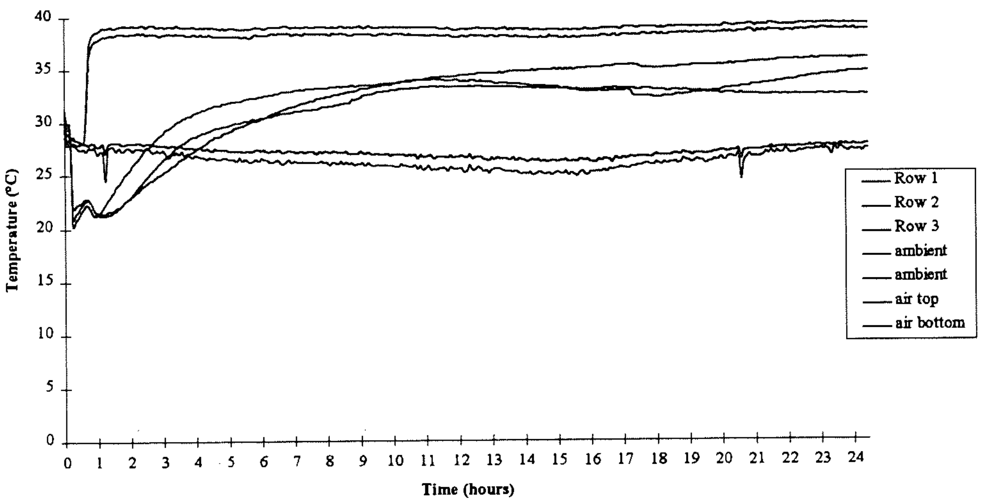


Figure 9.3

Weight changes during drying cuttlefish at 35°C

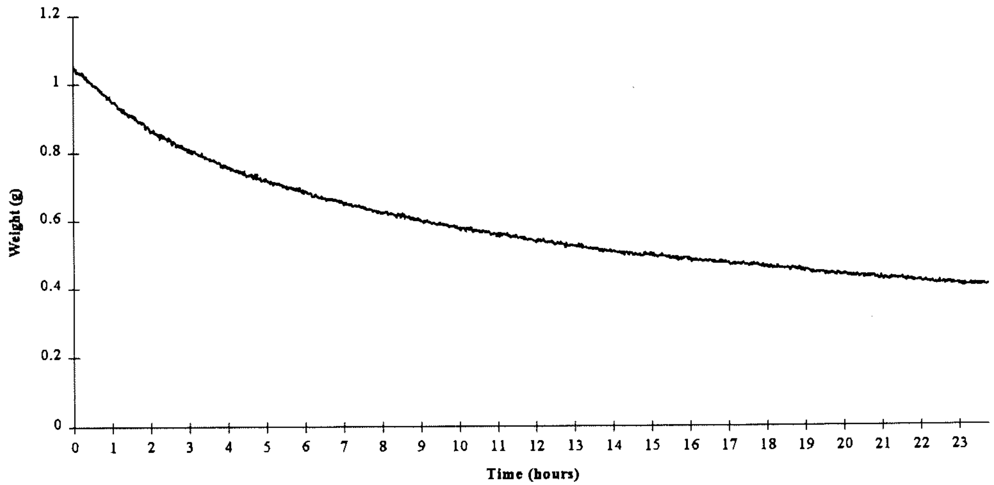


Figure 9.4

Humidity of air during drying of cuttlefish at 35°C

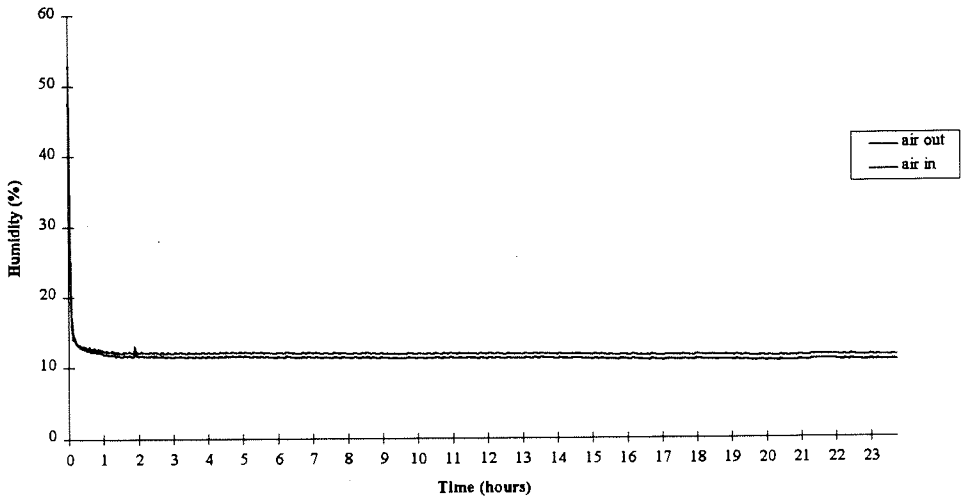


Figure 9.5

Temperatures during drying of squid at 45°C

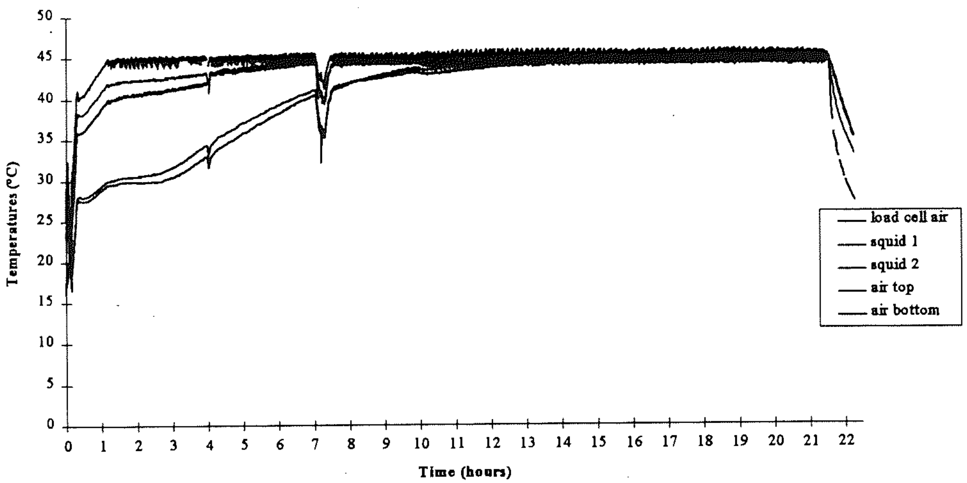


Figure 9.7

Humidity during drying split squid tubes at 35°C

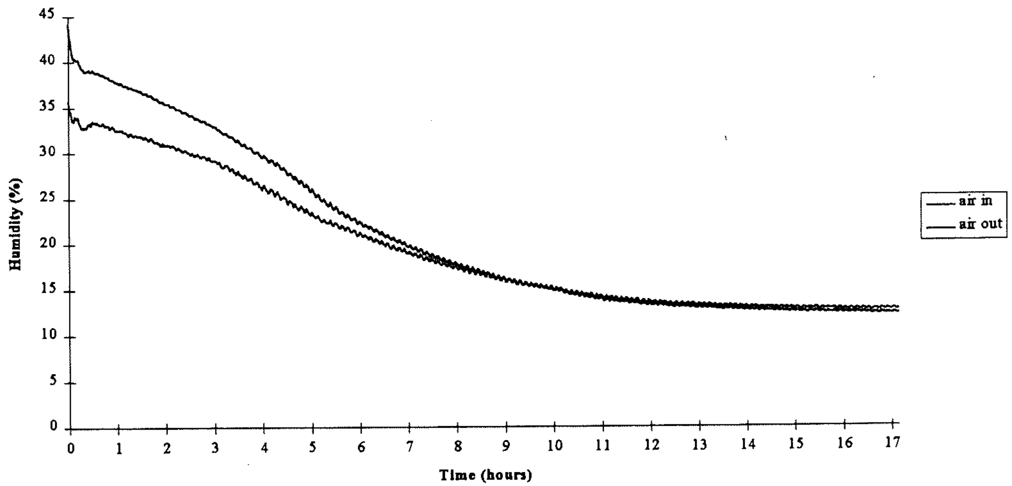


Figure 9.6

Weight changes during drying split squid tubes at 35°C

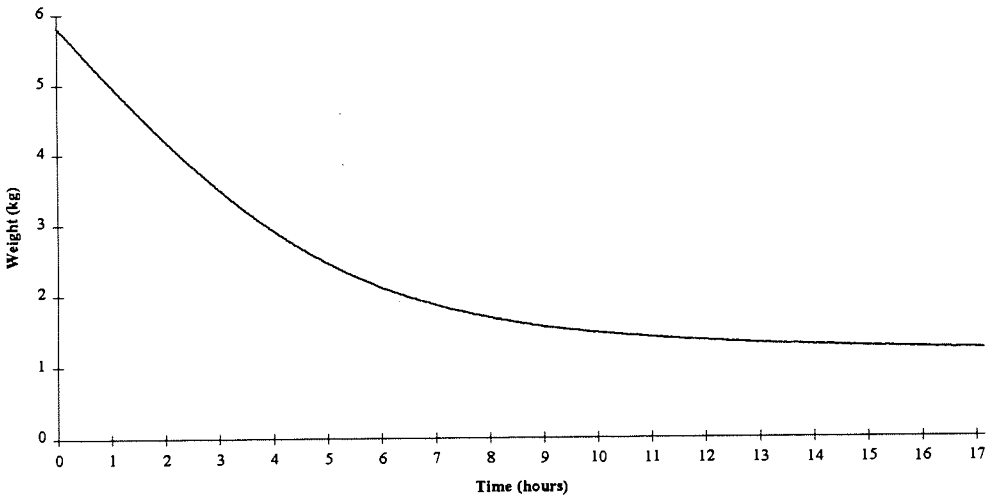


Figure 9.8

Temperatures during drying split squid tubes at 35°C

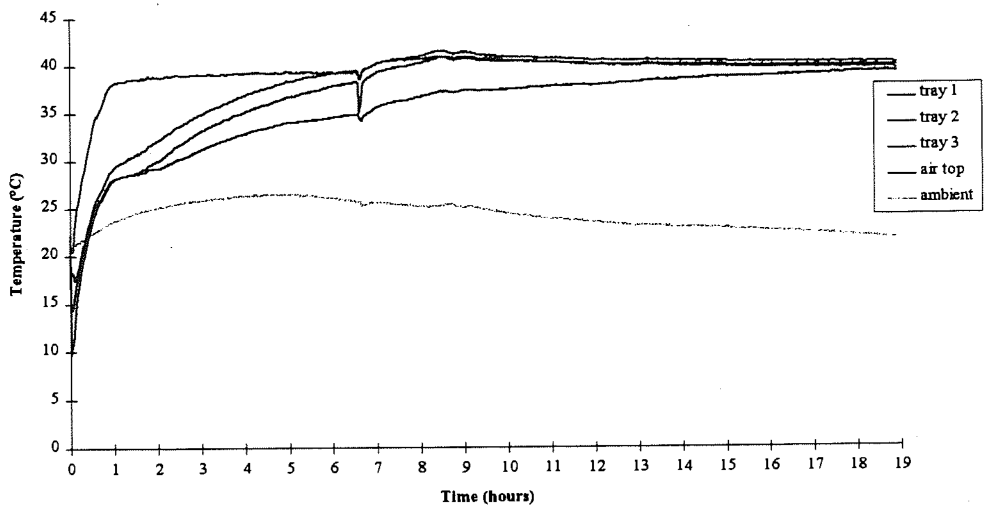


Figure 9.9

Weight changes during drying split squid tubes at 35°C

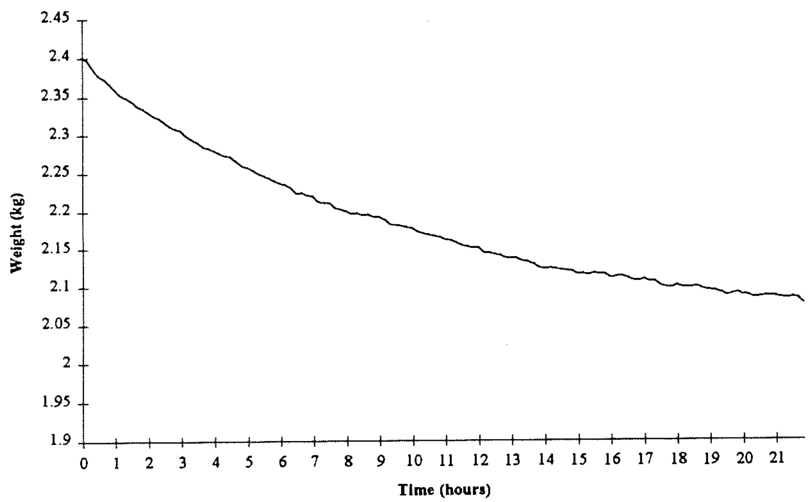


Figure 9.10

Humidity during drying split squid tubes at 35°C

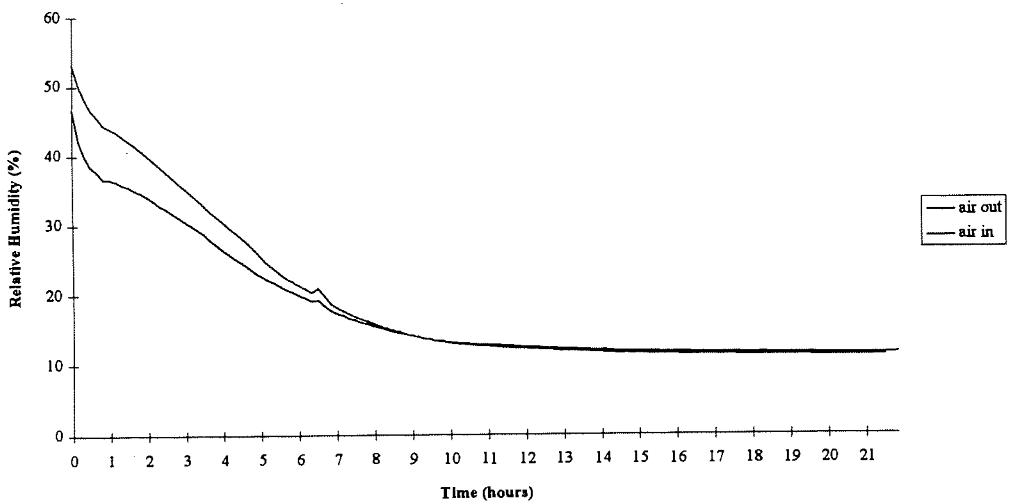


Figure 9.11

Temperatures during drying split squid at 45°C

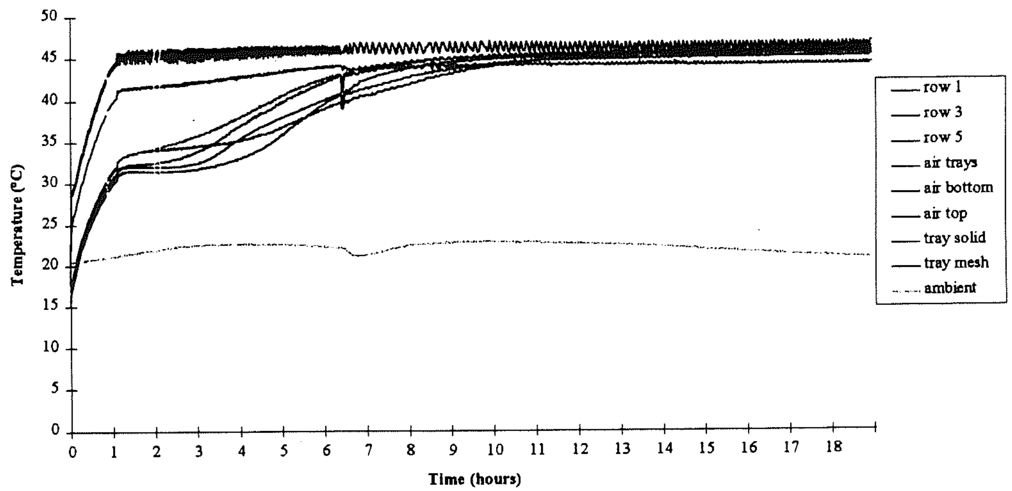


Figure 9.12

Weight changes during drying split squid tubes at 45°C

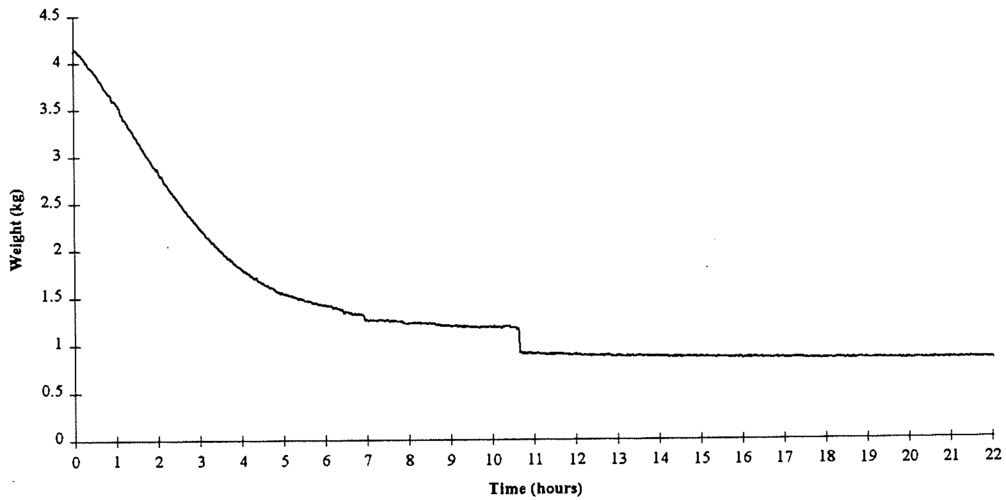


Figure 9.13

Humidity during drying split squid tubes at 45°C

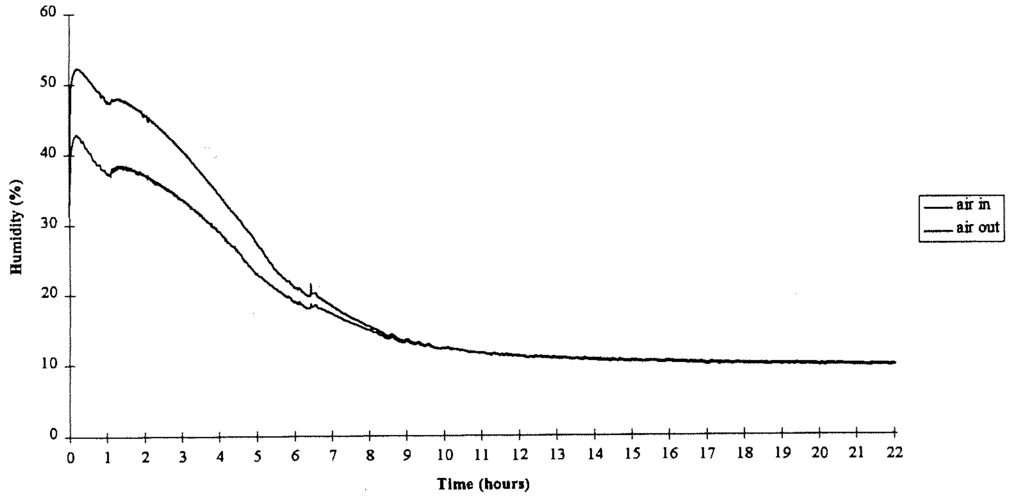


Figure 10.2

Weight changes during drying scallops at 35°C

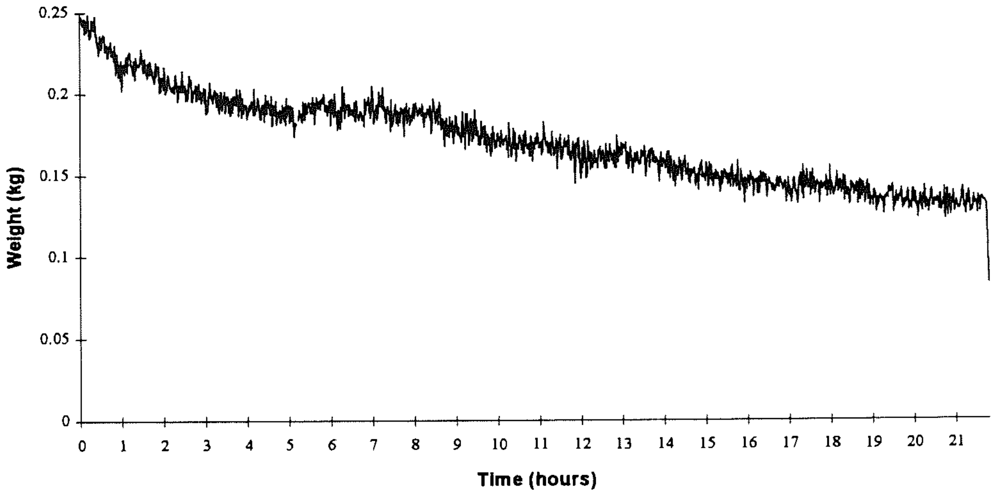


Figure 10.1

Temperatures during drying scallops at 35°C

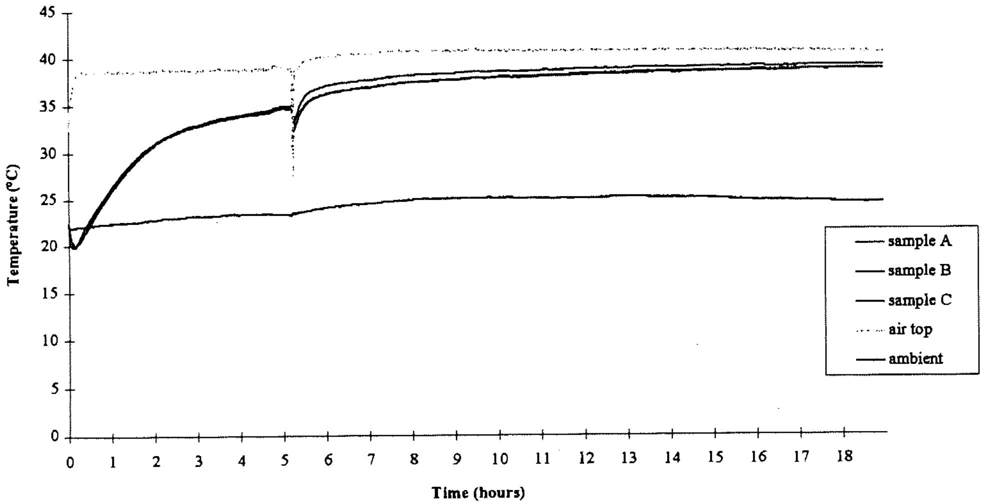


Figure 10.3

Humidity during drying scallops at 35°C

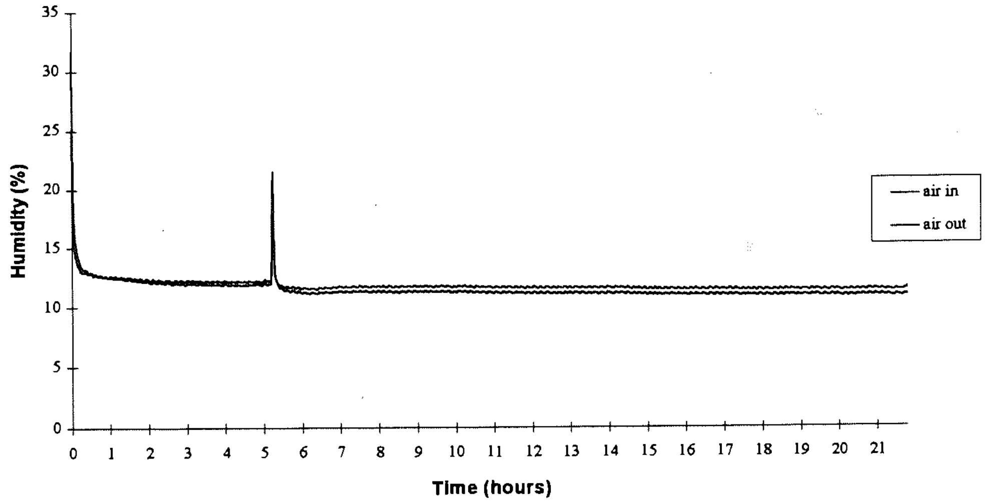


Figure 10.4

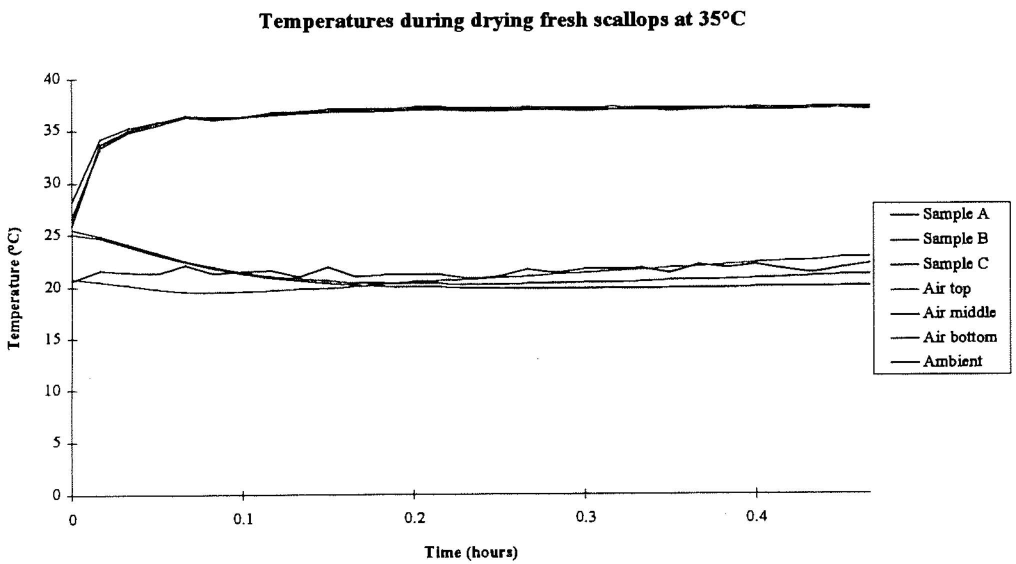


Figure 10.6

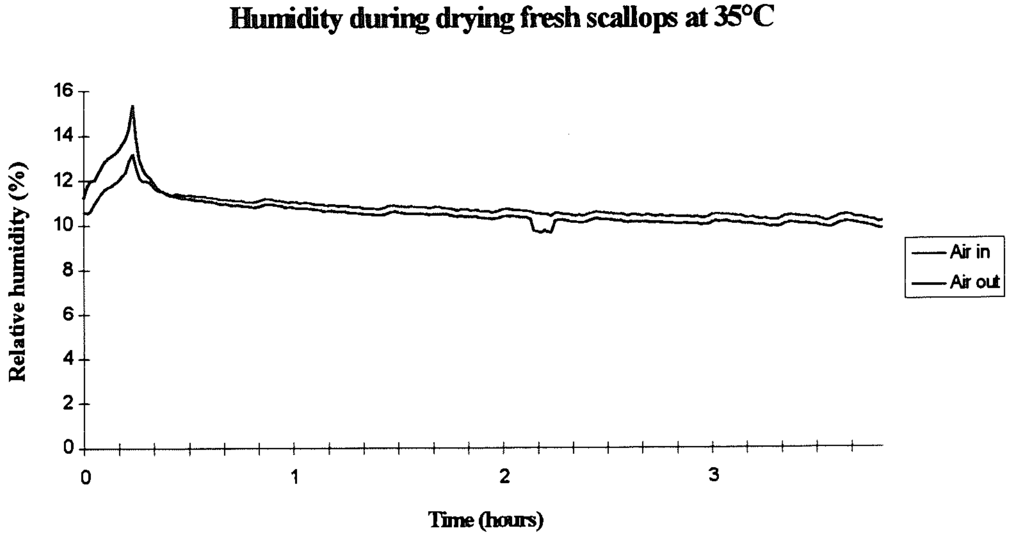


Figure 10.5

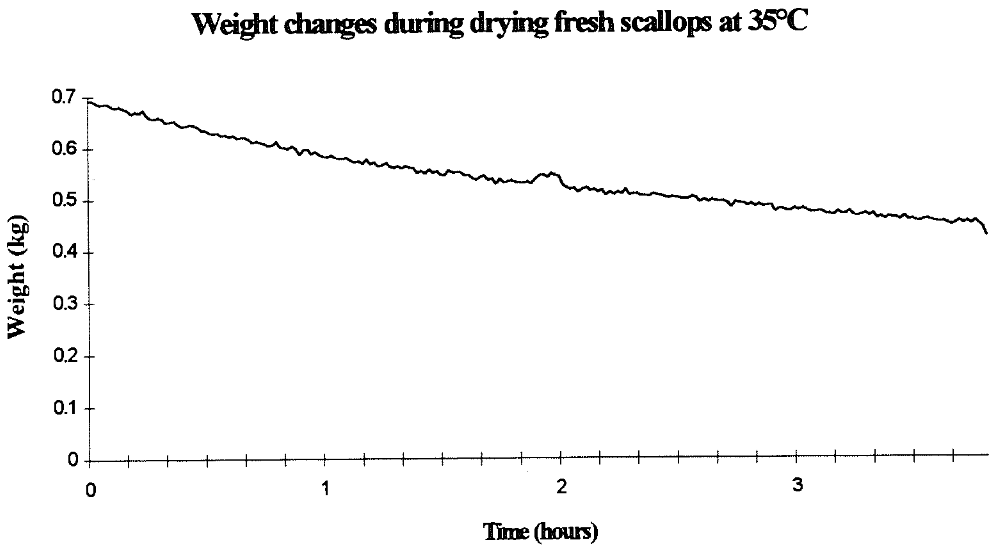


Figure 10.7

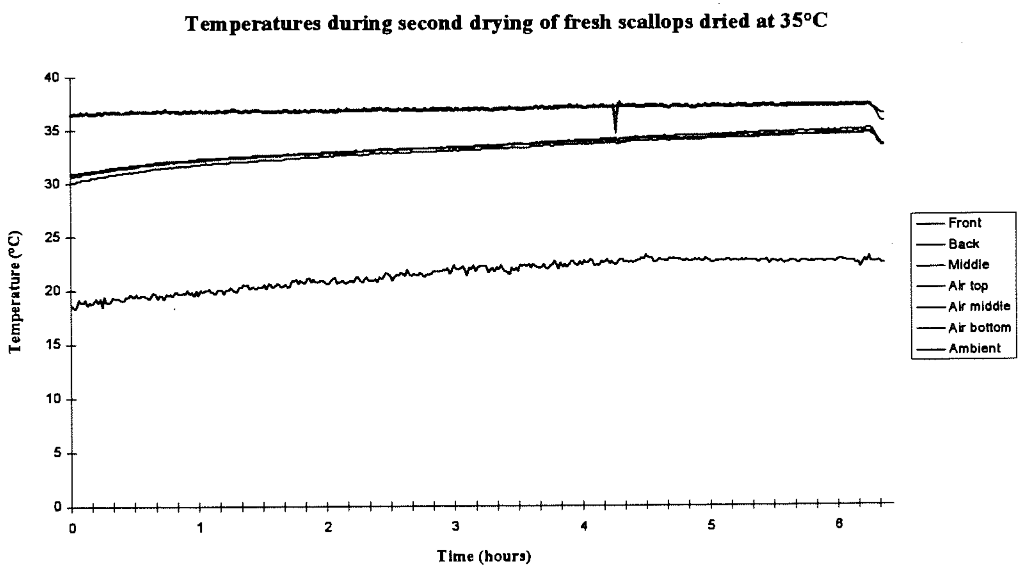


Figure 10.8

Weight changes during second drying of fresh scallops at 35°C

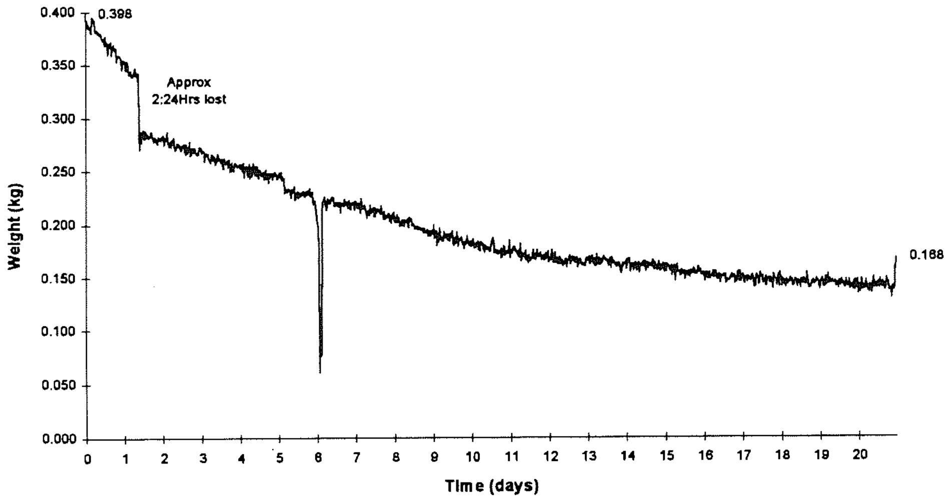


Figure 10.9

Humidity during second drying of fresh scallops at 35°C

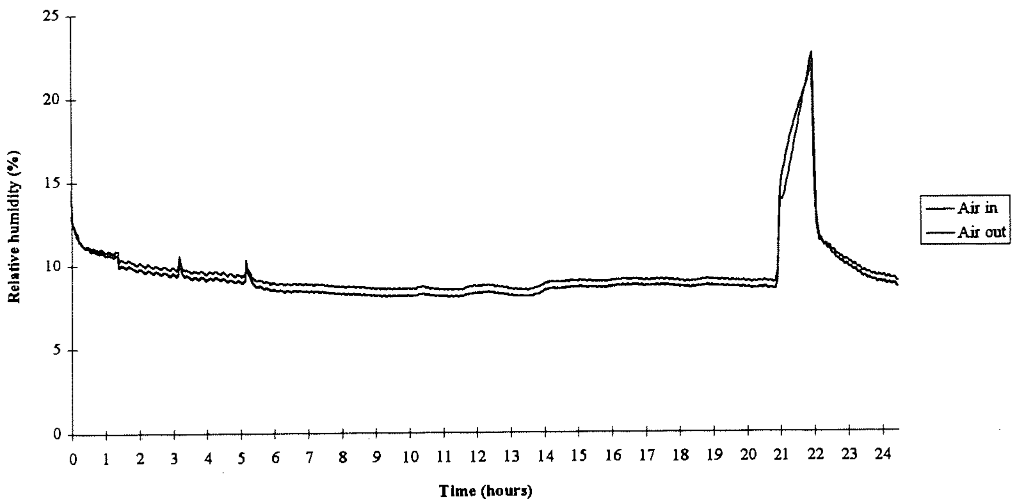


Figure 10.10

Temperatures during intermittent drying of scallops at 35°C
2 minute boil

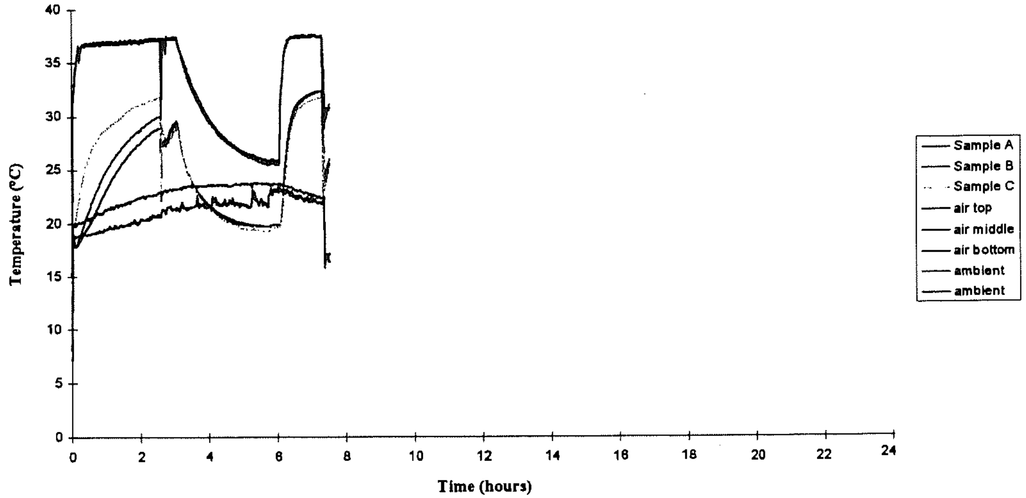


Figure 10.11

Weight changes and power consumption during intermittent drying of scallops at 35°C, 2 minute boil

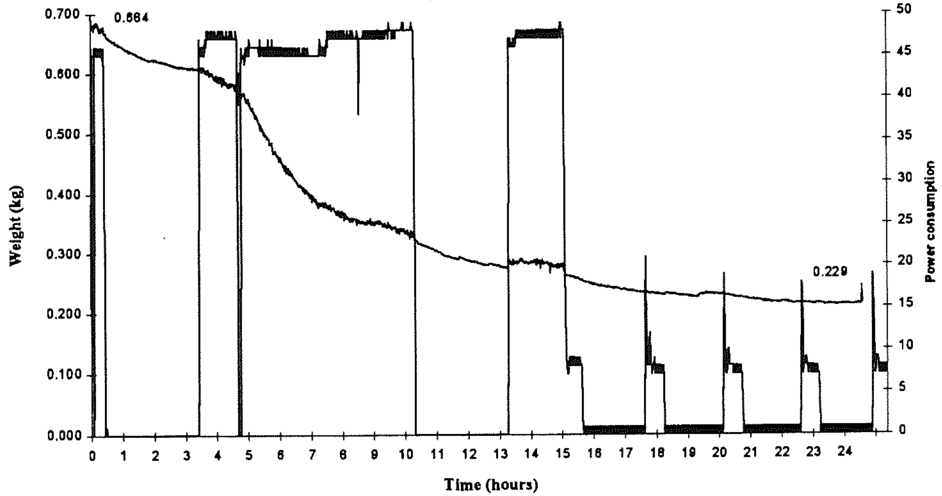


Figure 10.12

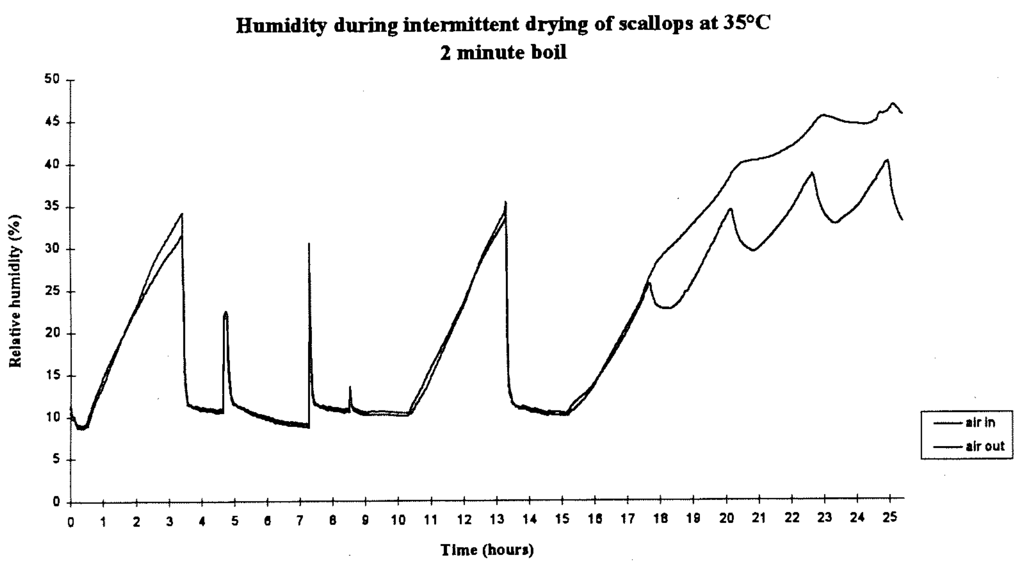


Figure 10.13

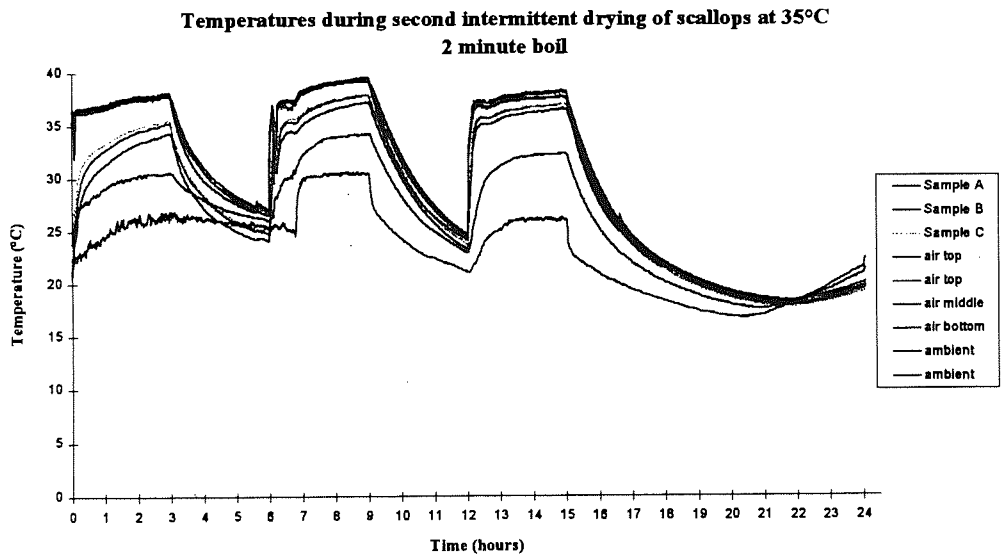


Figure 10.14

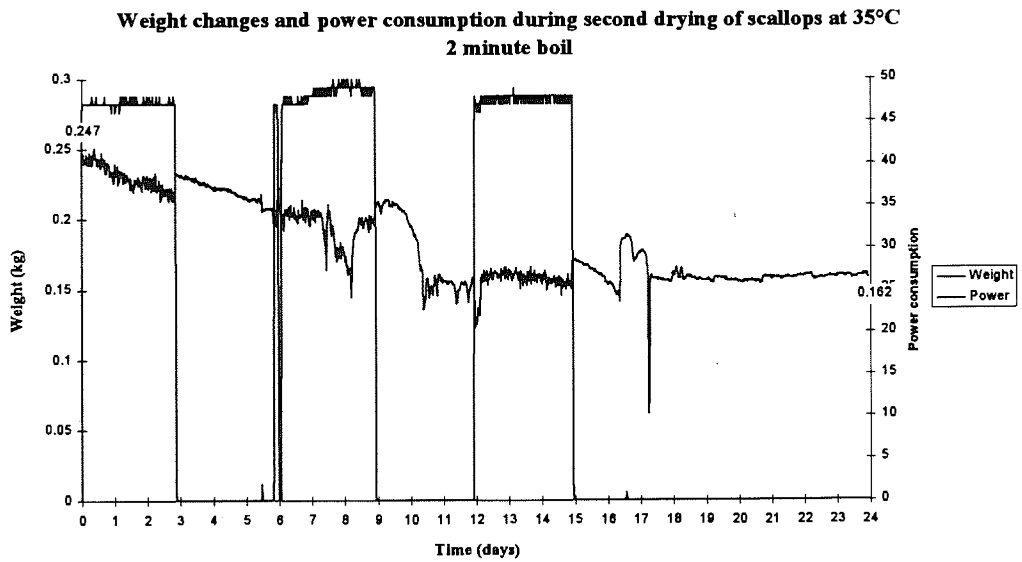


Figure 10.15

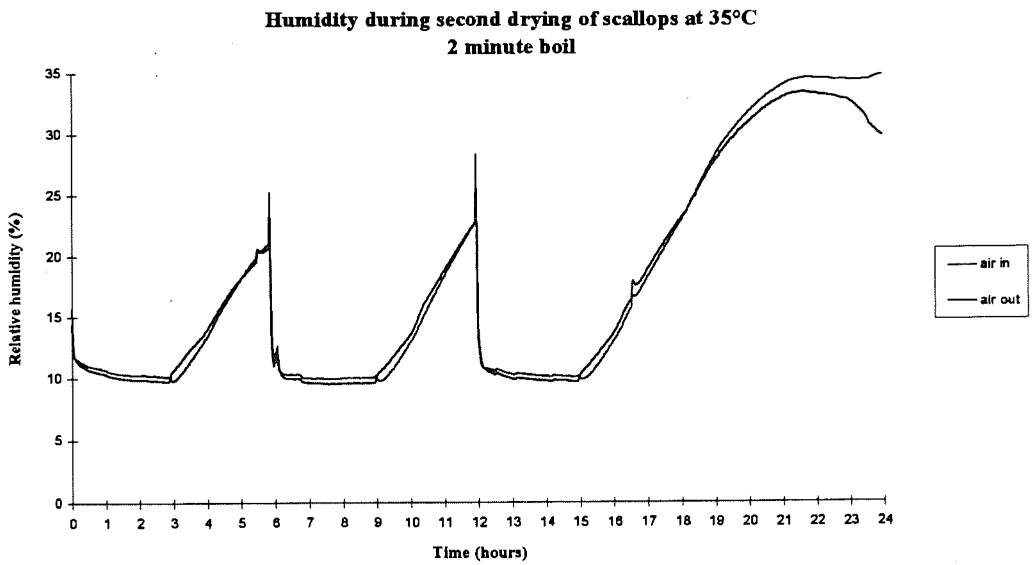


Figure 10.16

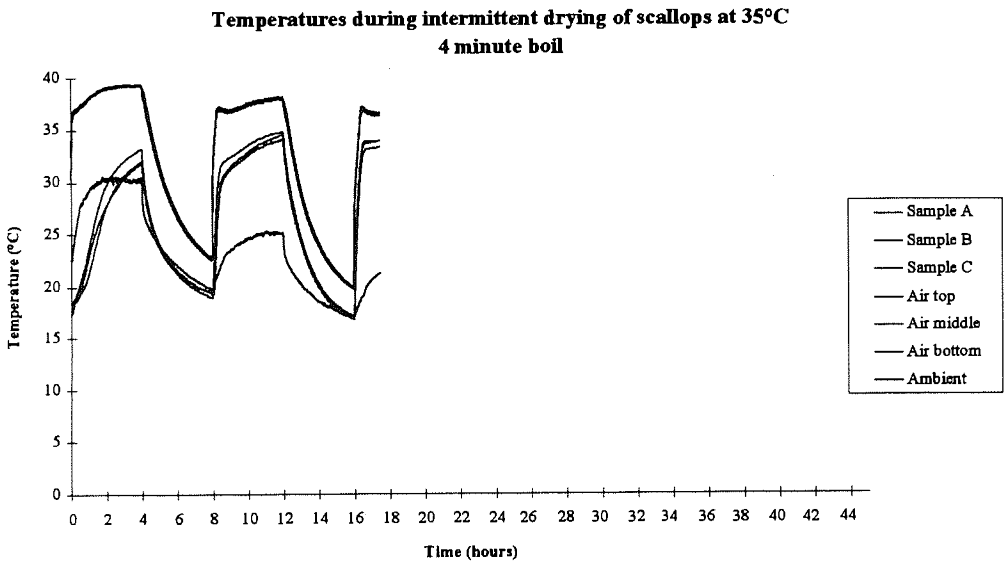


Figure 10.17

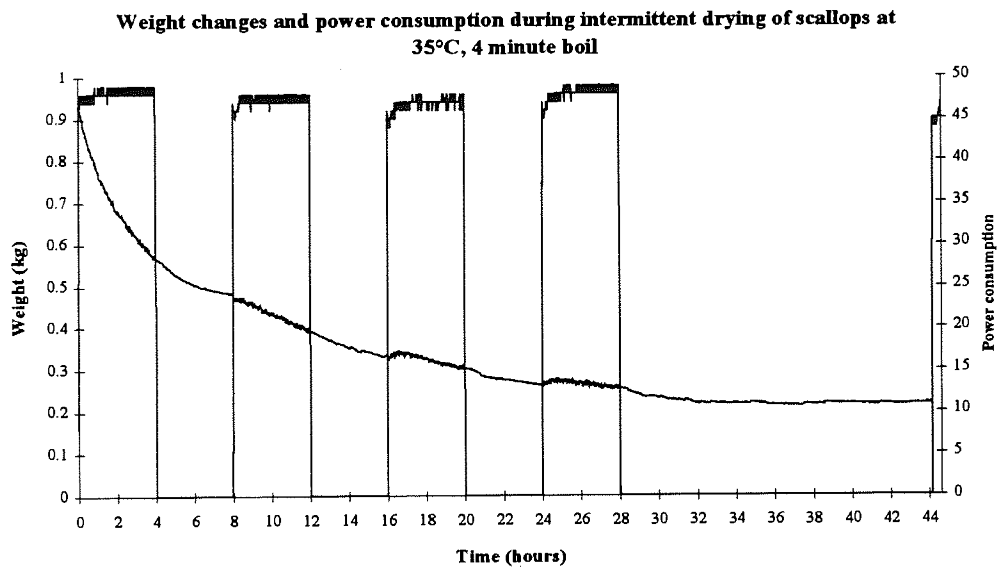


Figure 10.18

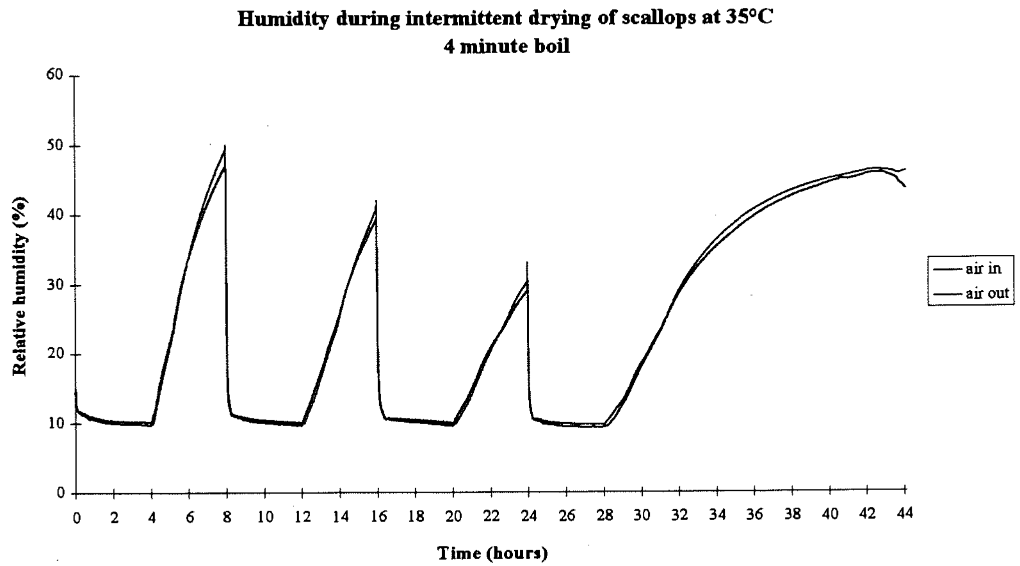


Figure 10.19

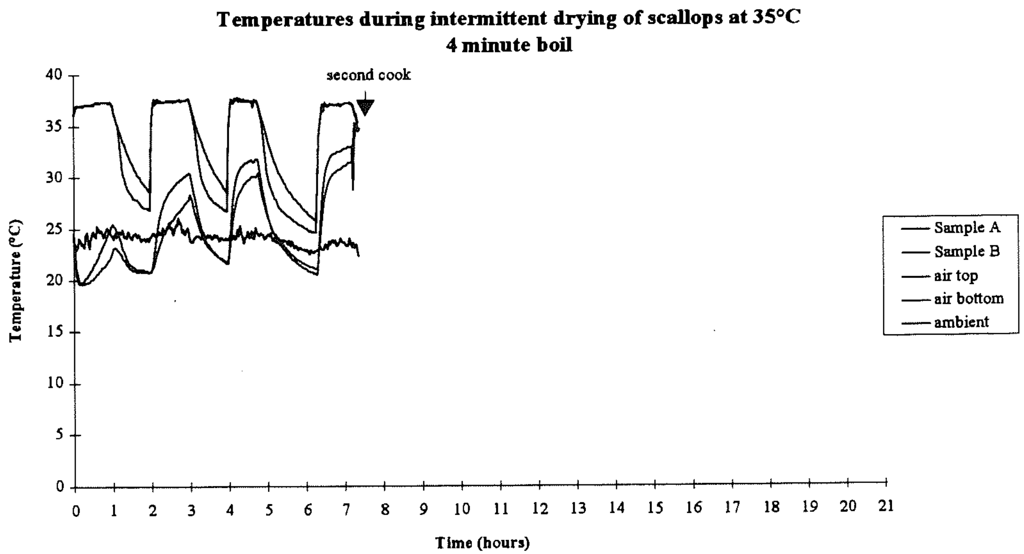


Figure 10.20

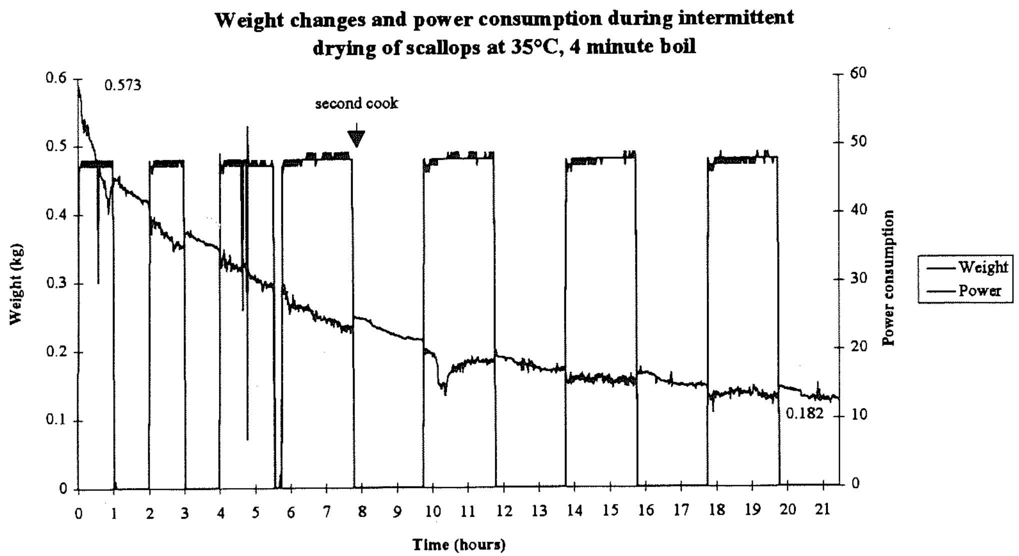


Figure 10.22

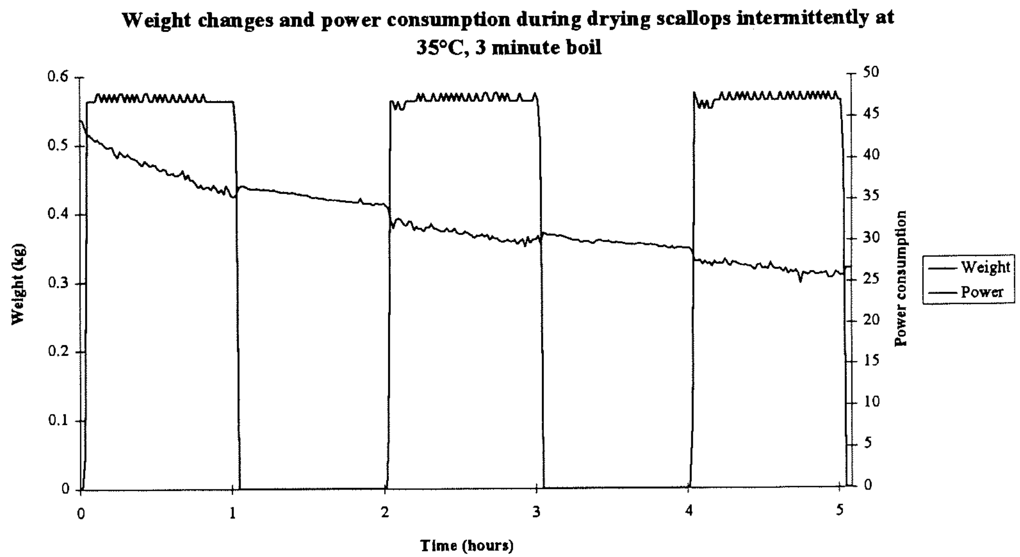


Figure 10.21

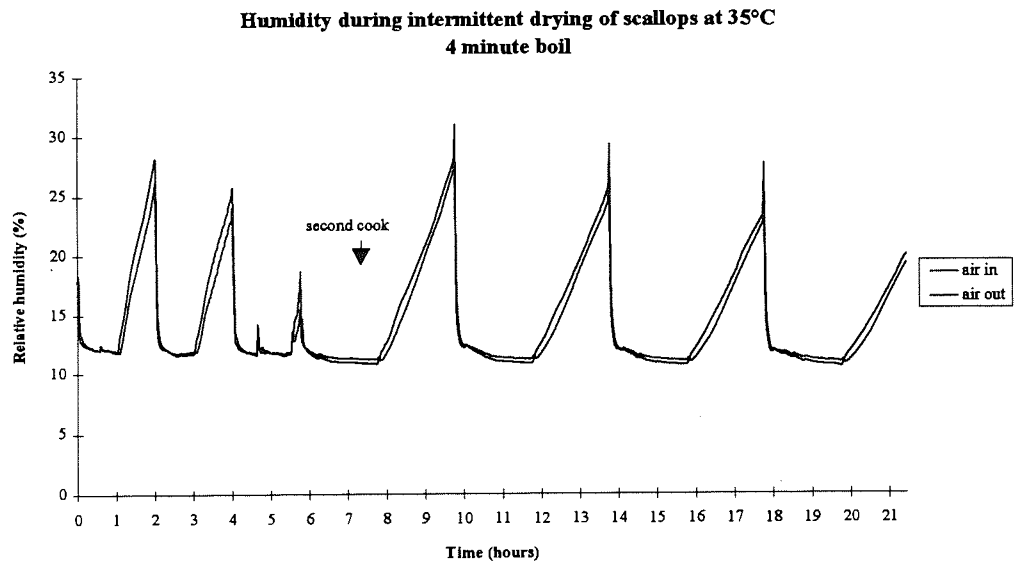


Figure 10.23

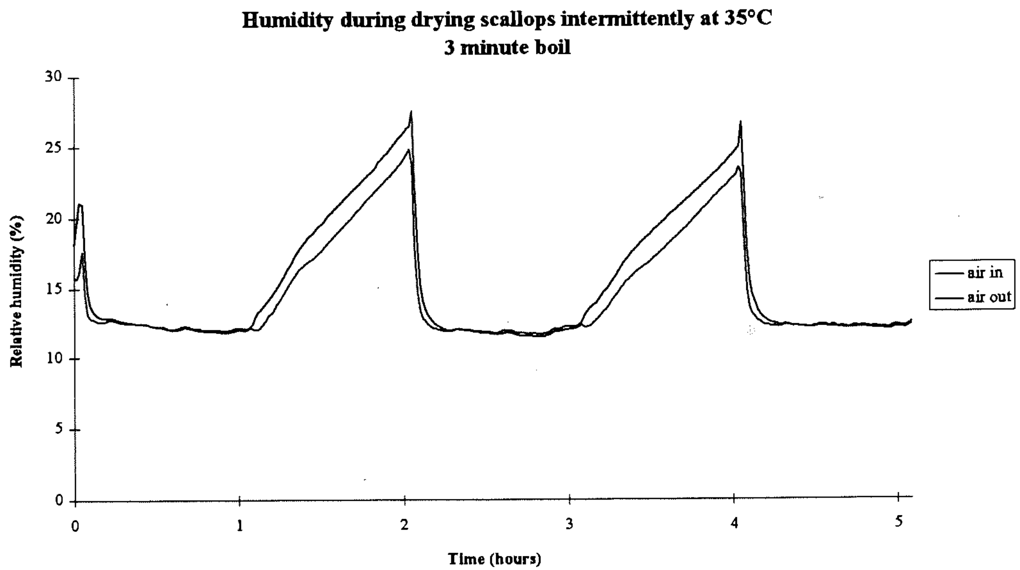


Figure 11.1

Temperatures during drying of raw pearl meat at 38°C

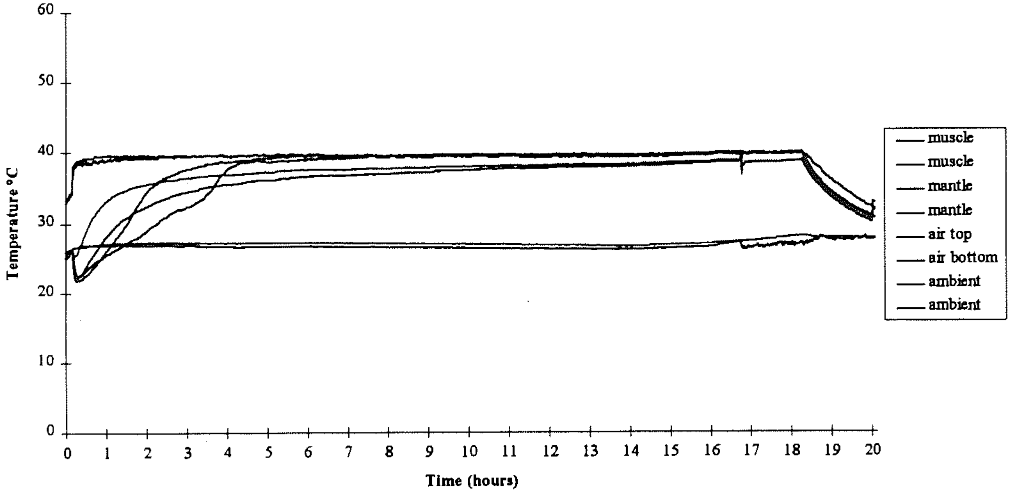


Figure 11.2

Temperatures during second drying of raw pearl muscle at 45°C

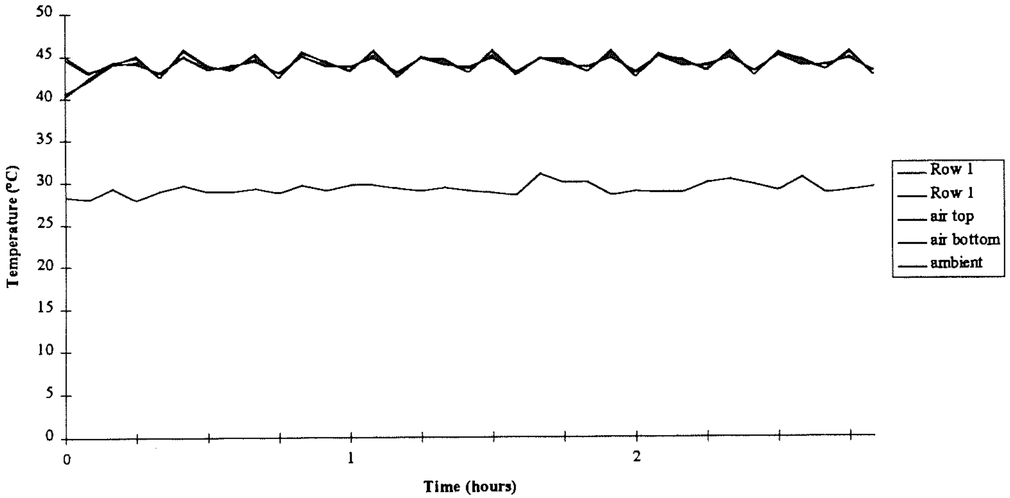


Figure 11.3

Weight changes during second drying of raw pearl muscle at 45°C

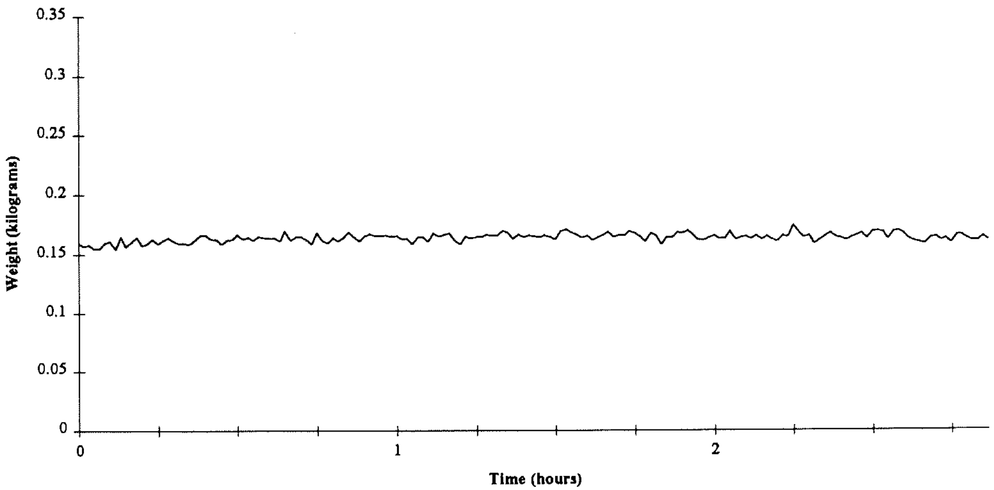


Figure 11.4

Humidity during second drying of raw pearl muscle at 45°C

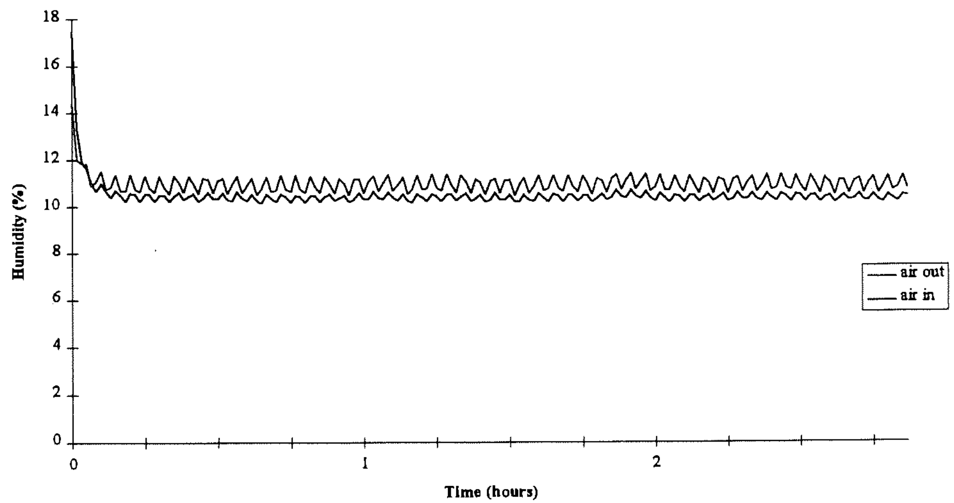


Figure 11.8

Temperatures during drying of cooked pearl meat at 35°C

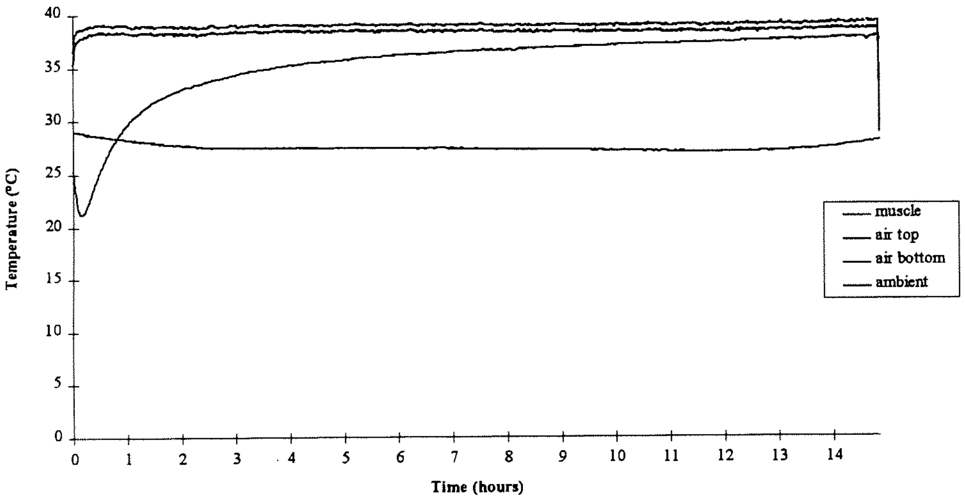


Figure 11.9

Weight changes during drying of cooked pearl meat at 35°C

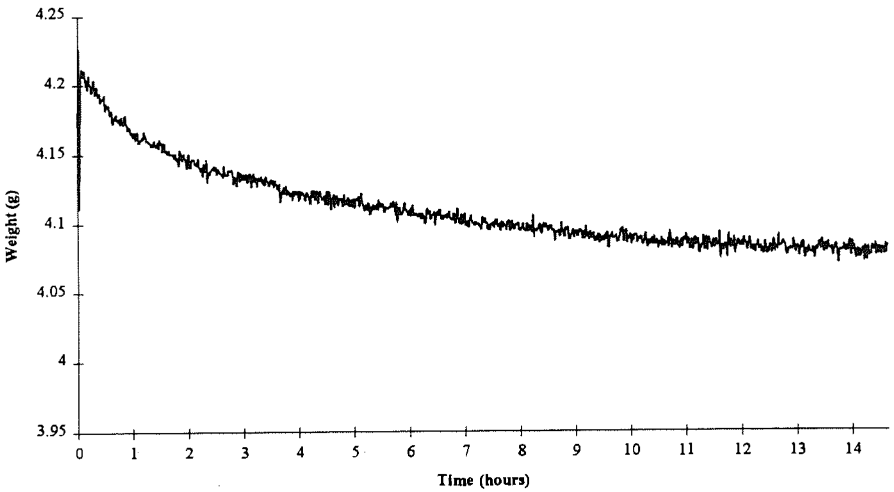


Figure 11.7

Humidity of air during drying of cooked pearl meat at 35°C

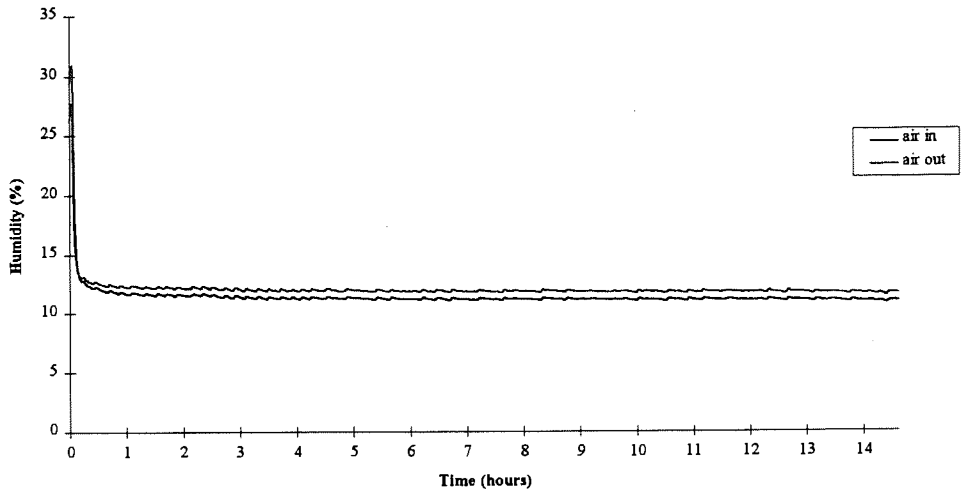


Figure 11.8

Temperature during second drying of cooked pearl muscle at 45°C

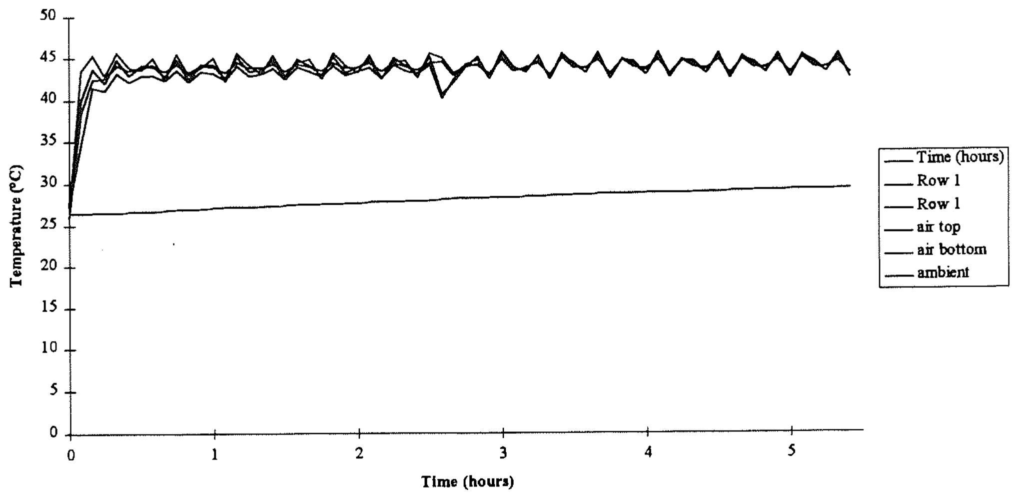


Figure 11.9

Weight changes during second drying of cooked pearl muscle at 45°C

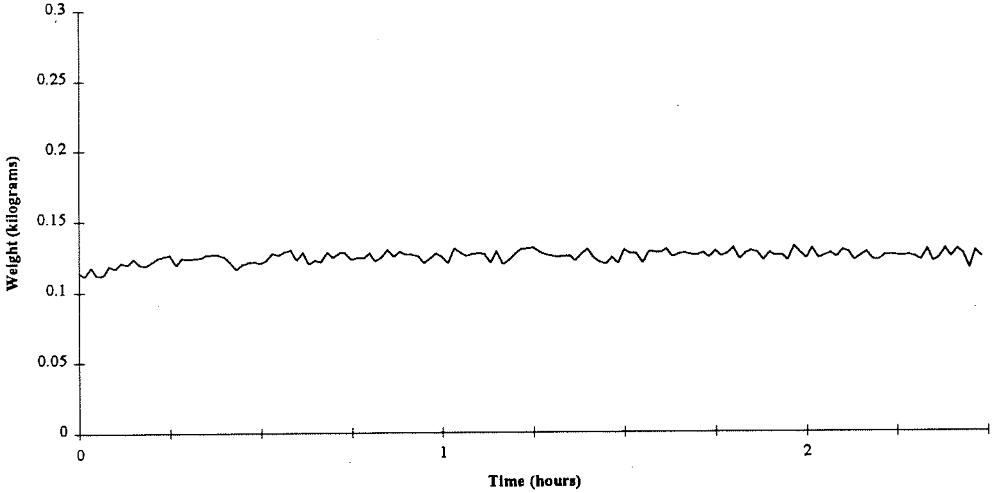


Figure 11.11

Temperatures during intermittent drying of pearl muscle at 35°C

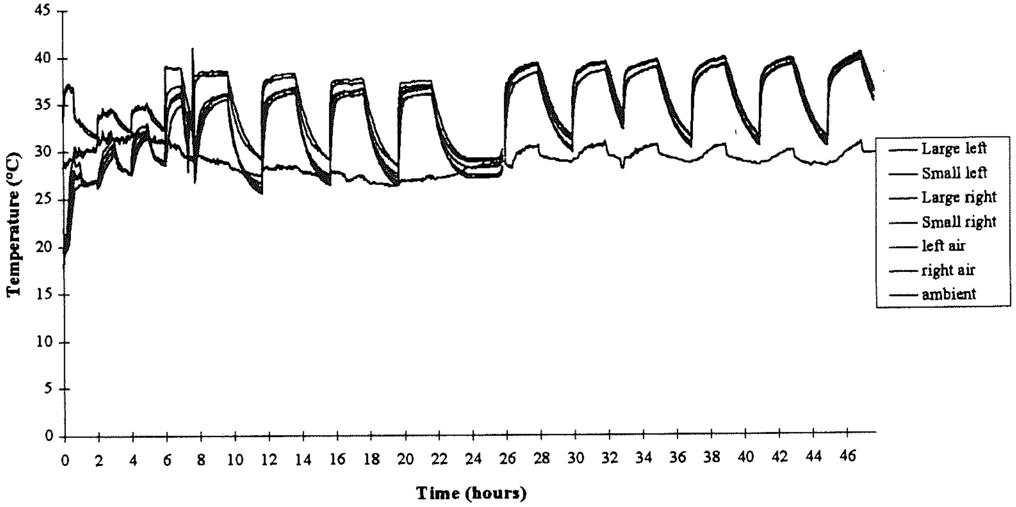


Figure 11.10

Humidity during second drying of cooked pearl muscle at 45°C

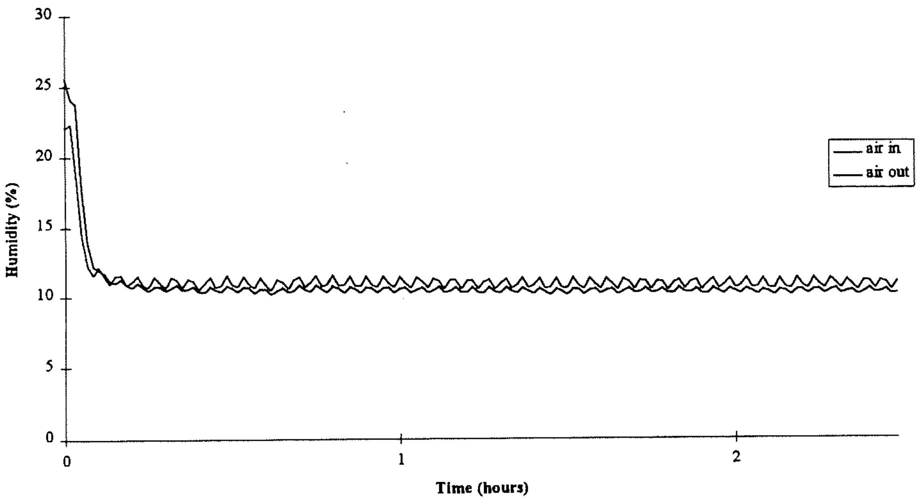


Figure 11.12

Weight changes and power consumption during intermittent drying of cooked pearl meat at 35°C

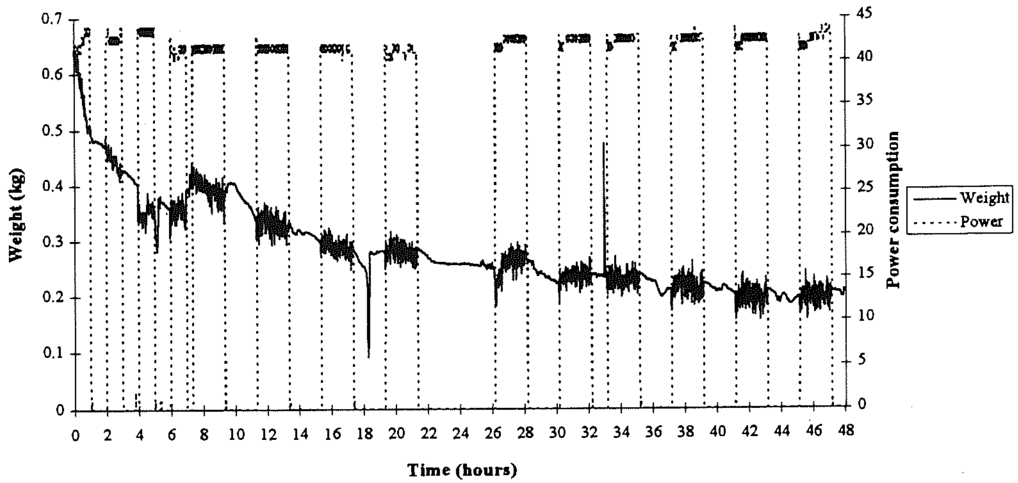


Figure 11.13

Humidity during intermittent drying of cooked pearl meat at 35°C

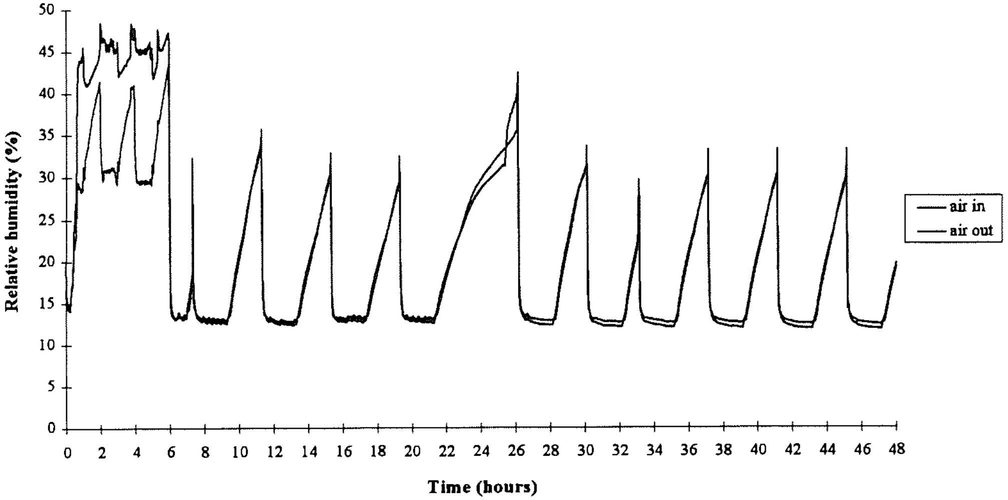


Figure 12.1

Temperatures of whelk during drying at 45°C

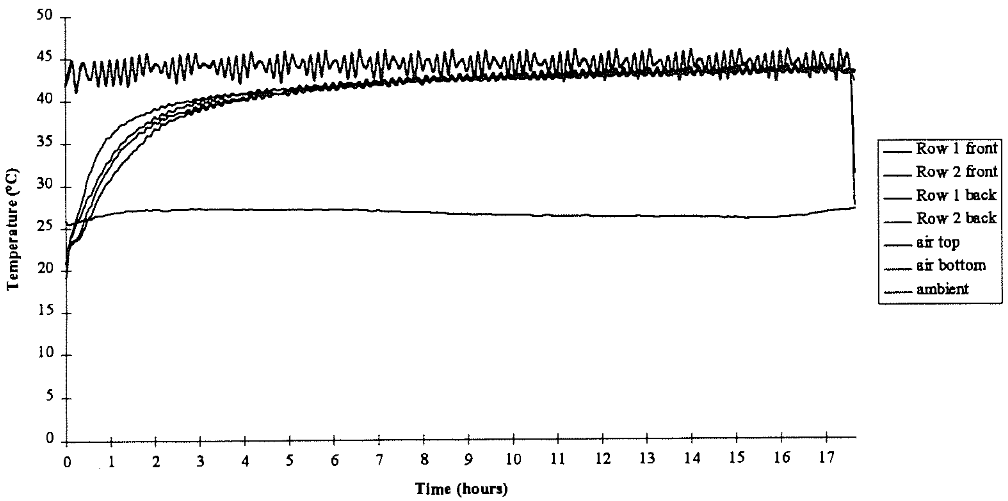


Figure 12.2

Weight changes during drying of whelks at 45°C

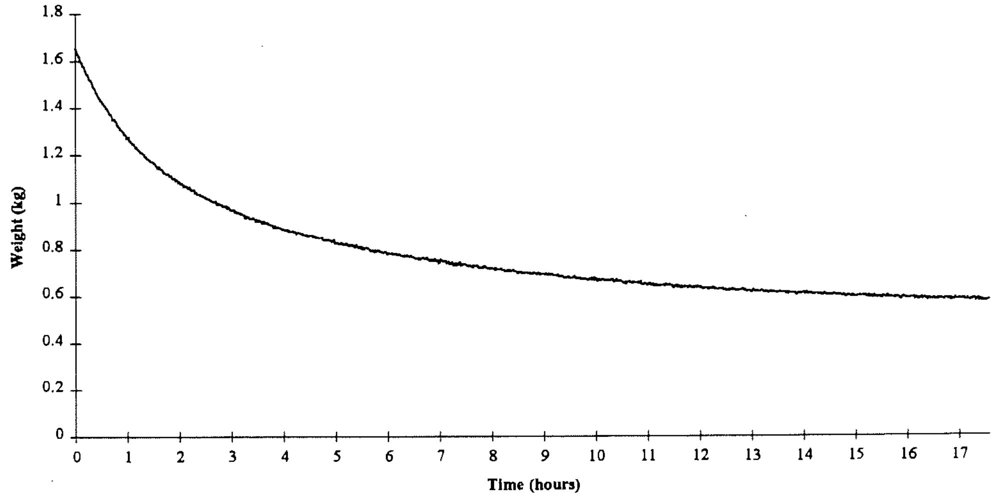
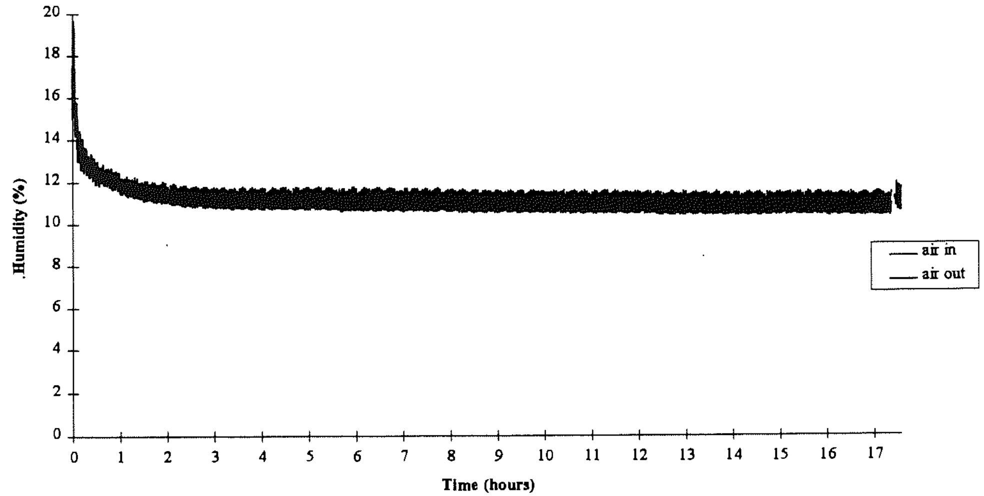


Figure 12.3

Humidity of air during drying of whelks at 45°C



APPENDIX 4 CRUSTACEA

Figure 13.1

Temperatures during drying whole coral prawns at 45°C

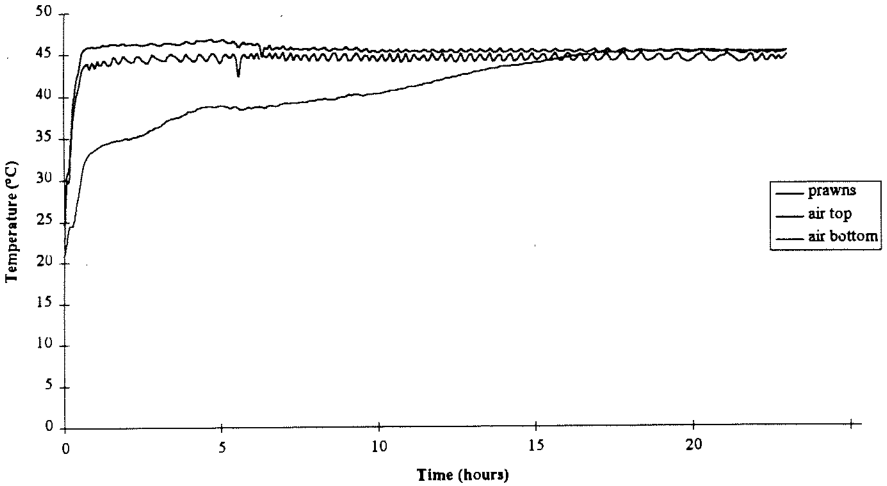


Figure 13.2

Temperatures during drying whole coral prawn at 35°C

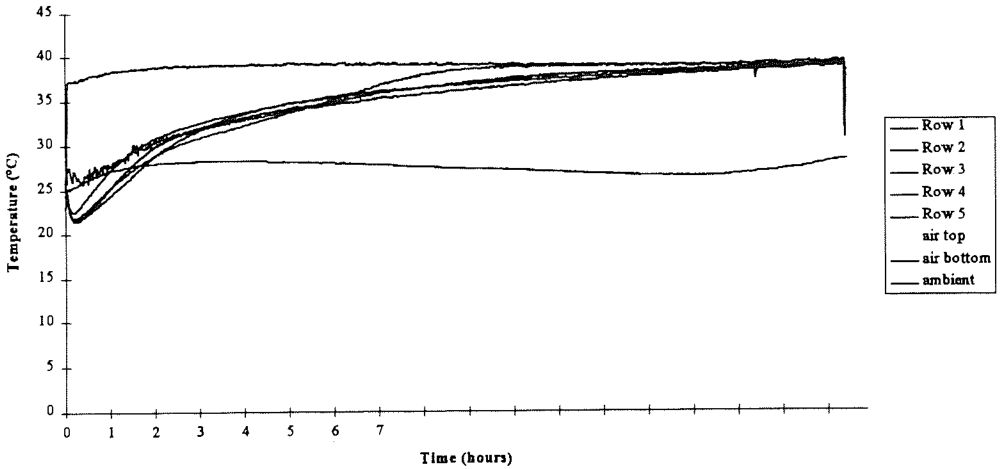


Figure 13.3

Weight changes during drying of whole coral prawns at 35°C

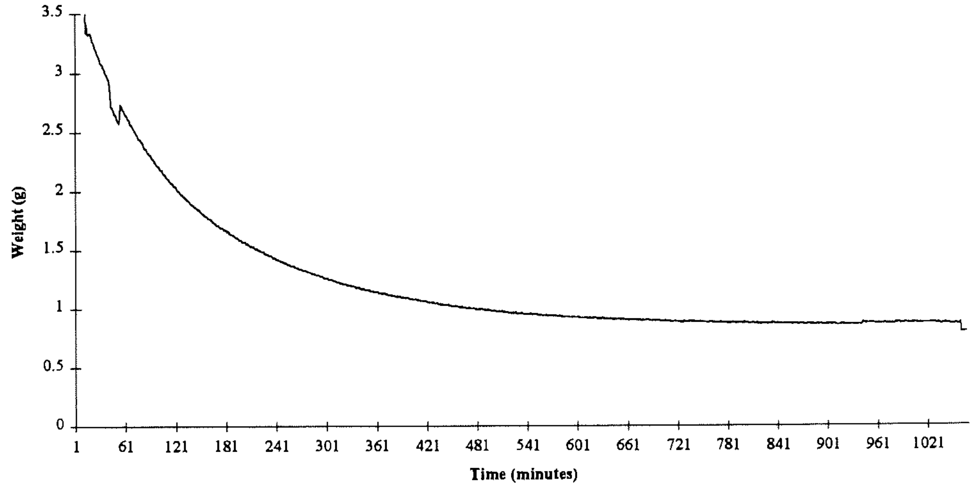


Figure 13.4

Humidity of air during drying of whole coral prawn at 35°C

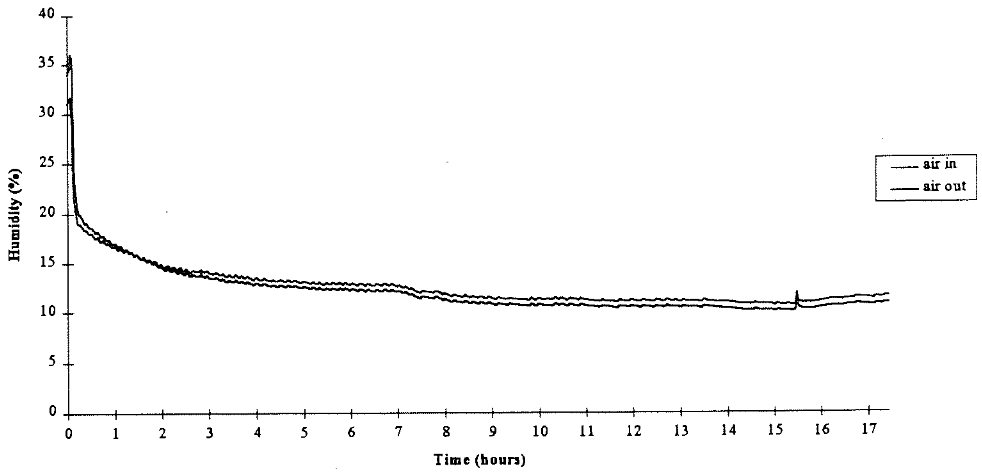


Figure 13.5

Temperatures during drying of cooked peeled prawns (150/200) at 35°C

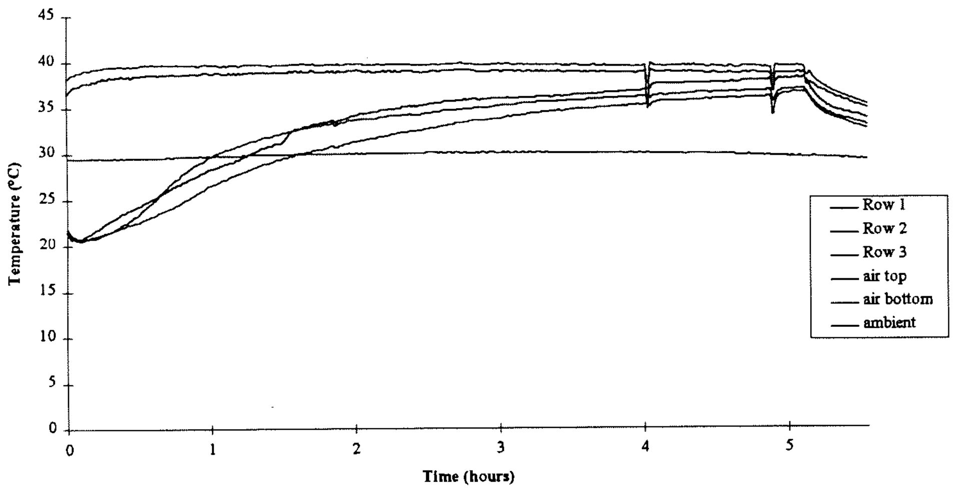


Figure 13.6

Weight changes during drying of cooked peeled prawns (150/200) at 35°C

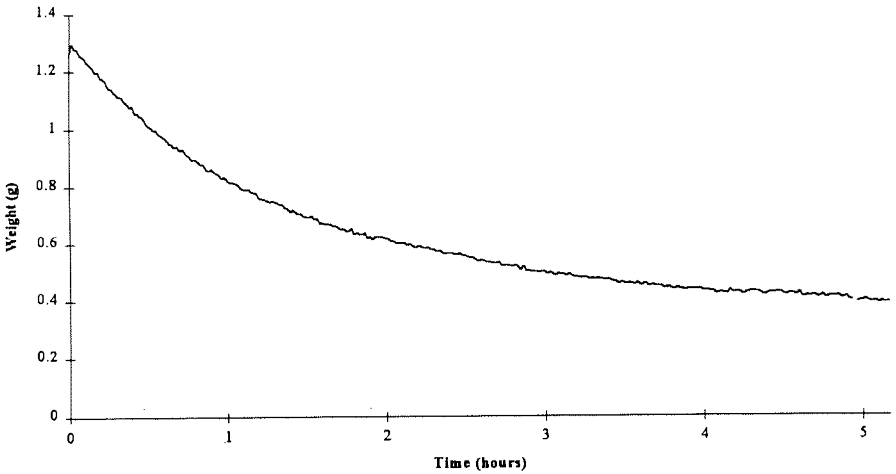


Figure 13.7

Humidity of air during drying of cooked peeled prawns (150/200) at 35°C

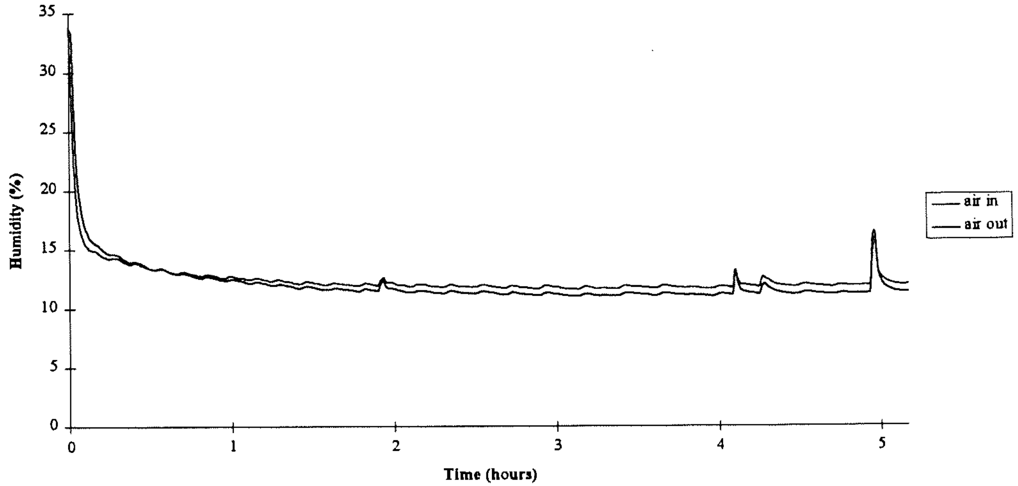


Figure 13.8

Temperatures during drying of cooked peeled prawns (100/200) at 45°C

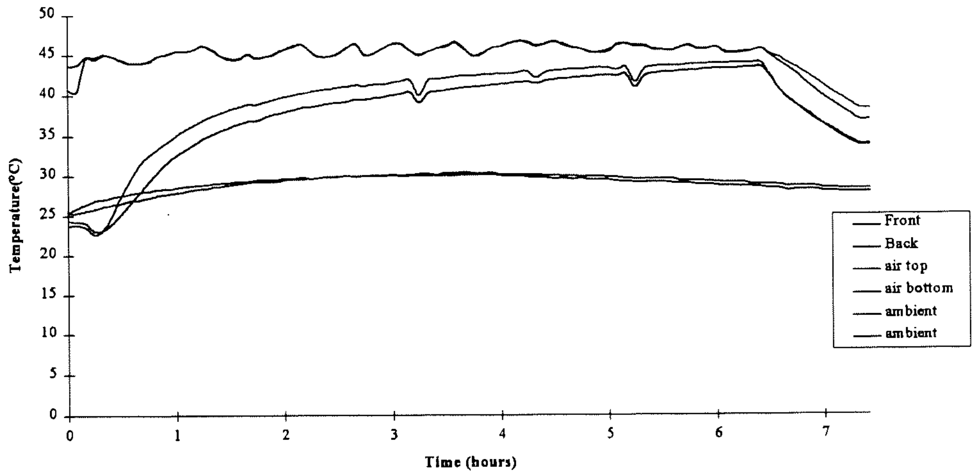


Figure 13.9

Weight changes during drying of cooked peeled prawns (100/200) at 45°C

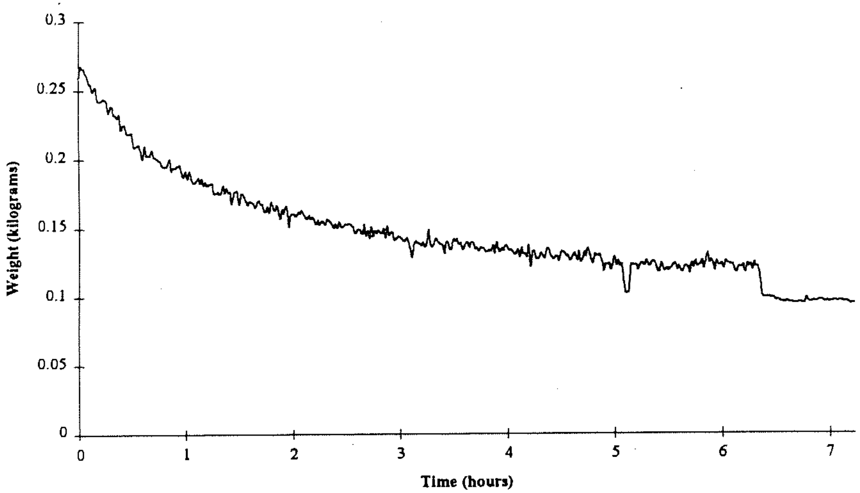


Figure 13.10

Humidity of air during drying of cooked peeled prawns (100/200) at 45°C

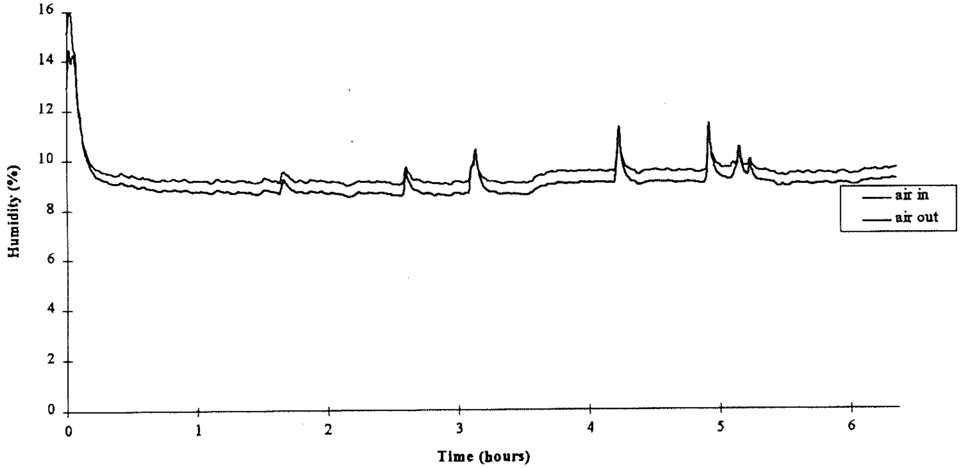


Figure 13.11

Temperatures during drying of cooked peeled prawns (300/500) at 55°C

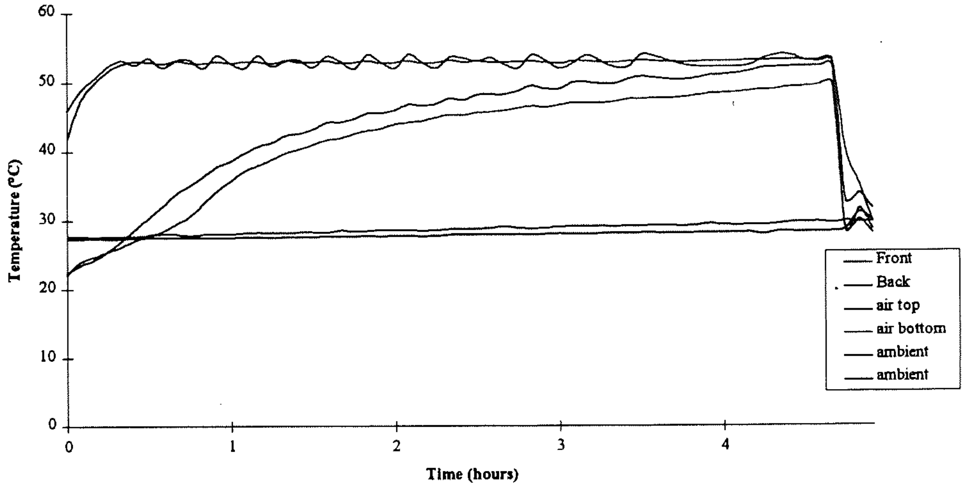


Figure 13.12

Weight changes during drying of cooked peeled prawns (300/500) at 55°C

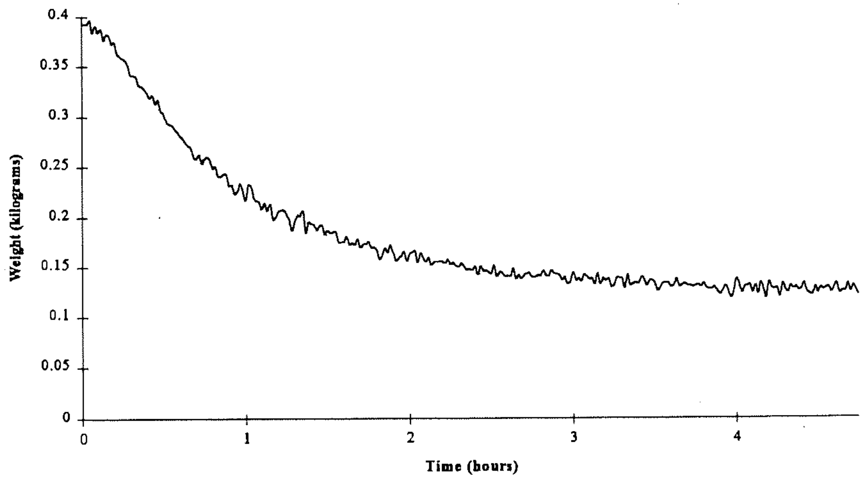


Figure 13.13

Humidity of air during drying of cooked peeled prawns (300/500) at 55°C

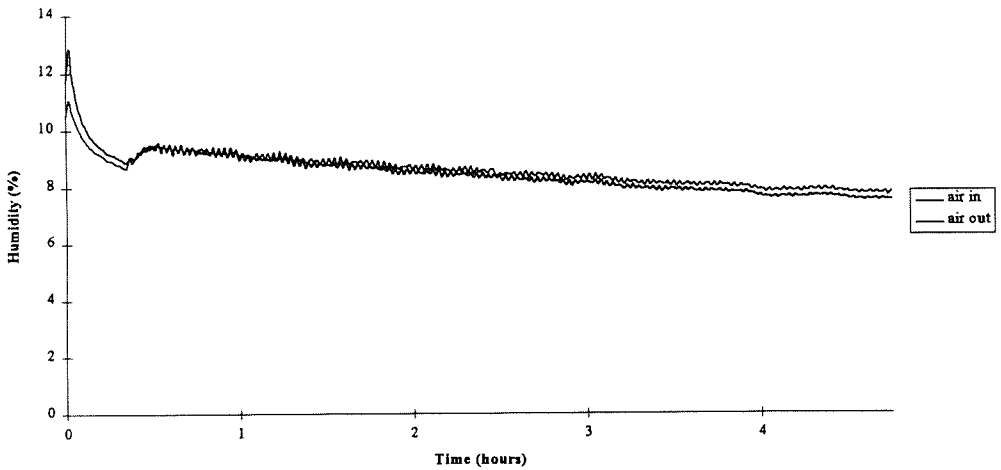


Figure 13.14

Temperatures during drying of cooked peeled prawns (300/500) at 55°C

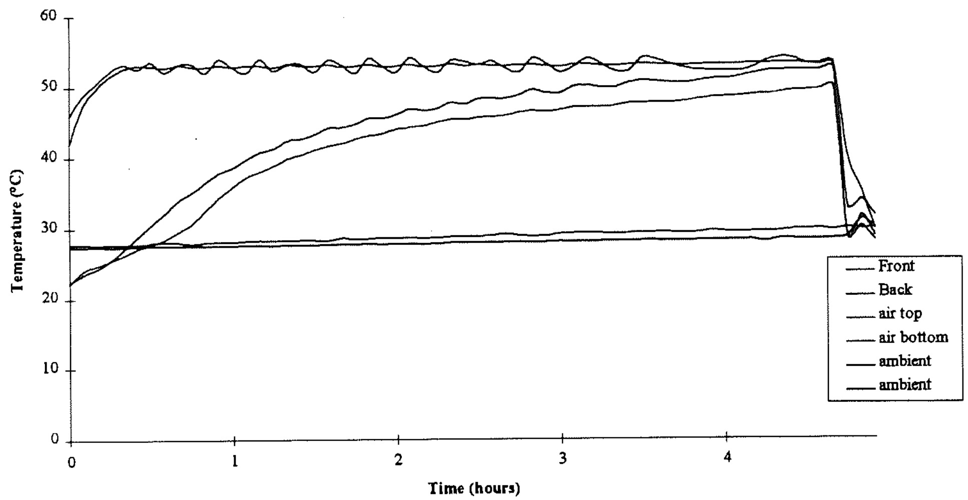


Figure 13.15

Weight changes during drying of cooked peeled prawns (300/500) at 55°C

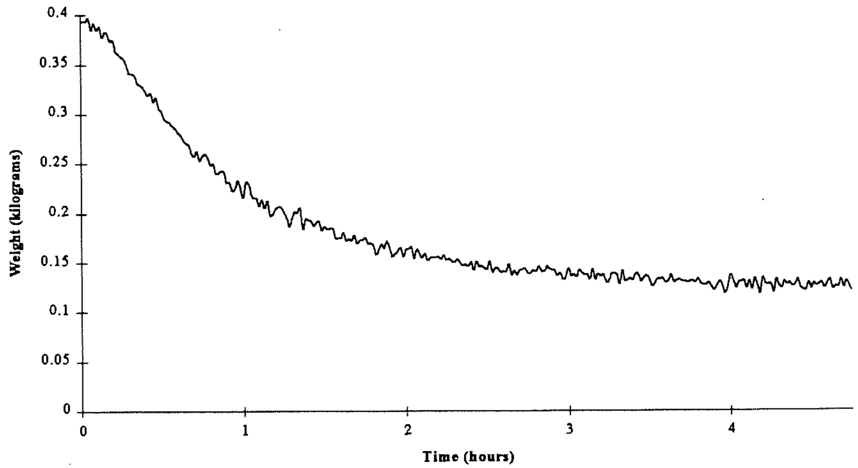


Figure 13.16

Humidity of air during drying of cooked peeled prawns (300/500) at 55°C

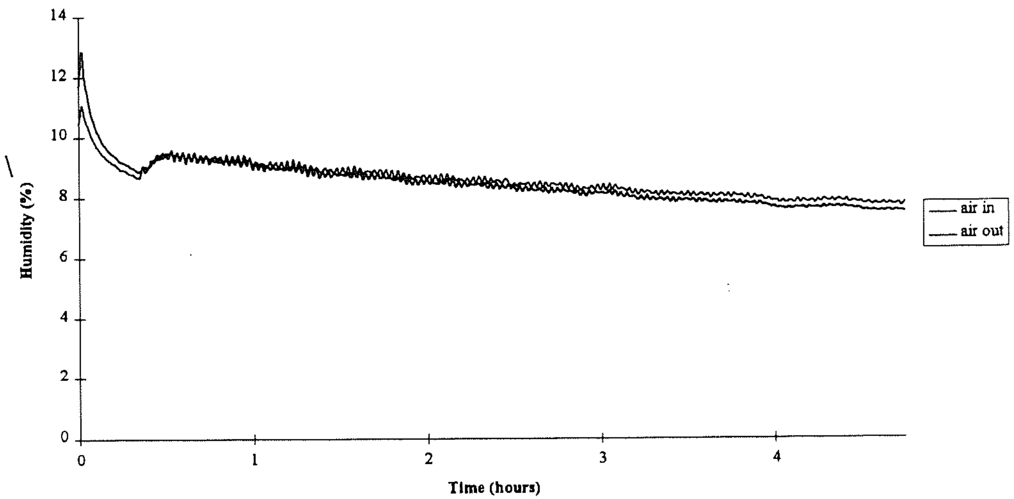


Figure 13.17

Temperatures during drying PUD prawns (100/200) at 55°C

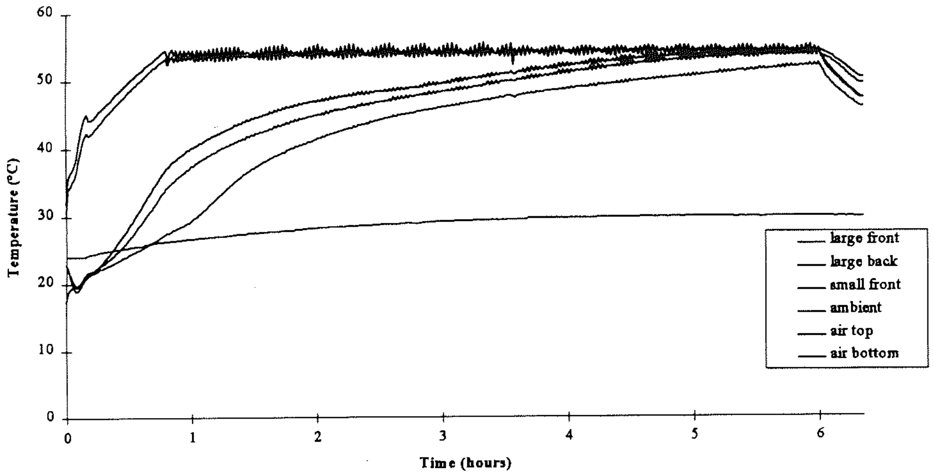


Figure 13.18

Weight changes during drying PUD prawns (100/200) at 55°C

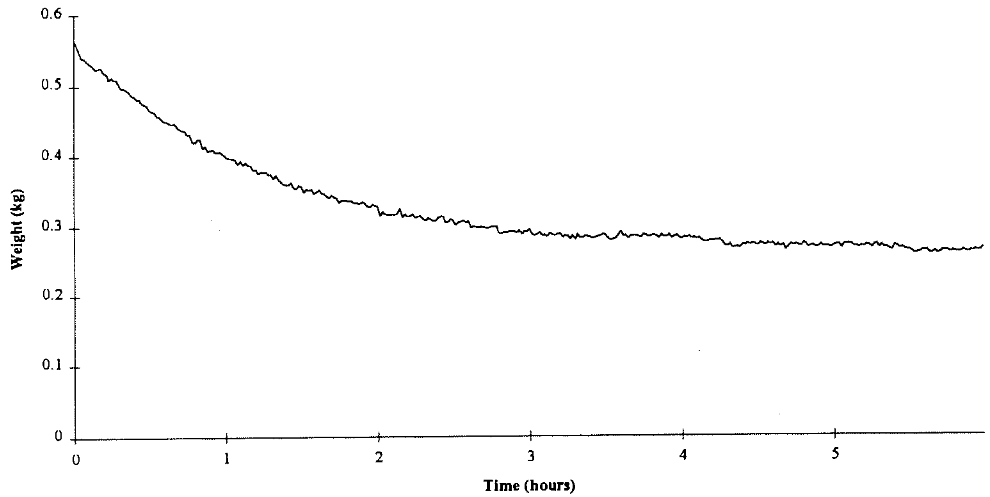
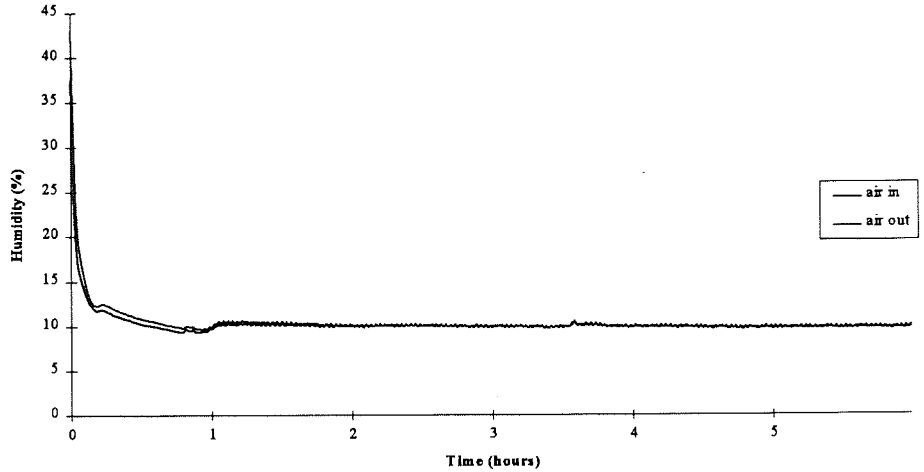


Figure 13.19

Humidity during drying PUD prawns (100/200) at 55°C



APPENDIX 5 BUDGET STATEMENT

Fisheries Research and Development Corporation

Statement of Receipts and Expenditure for the period ending 30 April 1997

Name of Research Organisation	FRDC Project Number	Title of Project
Department of Primary Industries	94/123 (97 55 015 AF5)	Value adding to seafood by application of modern drying techniques

Budget Summary	1994 /1995	1995 /1996	199 /19	199 /9 (1)
Original Budget	31,666.00	57,456.00		
Current Budget (2)				

Summary Receipts and Expenditure for the Project since commencement

	1994/95	1995/96	1996/97	199 /9
B/F	-	O/D 13,868.76	O/D 10,493.01	
FRDC Funds (Plus)	7,916.00	52,478.00	-	
Expenditure (Minus)	21,784.76	49,102.25	15,363.82	
Refunds(3)	-	-	-	
Balance C/F	O/D 13,868.76	O/D 10,493.01	O/D 25,856.83	

Details Financial Year to 30 April 1997

Funds Available

Balance brought forward from previous year		O/D 10,493.01
Total Funds received from FRDC during Financial Year 1996/97		-
Funds Available for FY 1996 - 97 (4)		O/D 10,493.01

Allocation FY(5)	Less Expenditure		
$.........................	Salaries	(627.63)	
$.........................	Travel	193.00	
$.........................	Operating	15,798.45	
$.........................	Capital	-	15,363.82
TOTAL $	Balance as at 30April 1997		O/D 25,856.83

Notes:

(1) Use the column for the final ONLY regardless of the length of the project.
(2) Total current budget shall not exceed Total original budget without approval in writing from the FRDC.
(3) Refunds should only be paid at completion of the project together with the final audited statement.
(4) ACTUAL EXPENDITURE (whether cash or accrual) ONLY. Commitment shall not be included.
(5) Show allocation for the current financial year. Transfers between budget heads allowed under 9(f) of the project Agreement, or the approved in writing by the FRDC shall be listed in the comments.

Comments

Certified by:

S. Hallam

(Signature)

Sue Hallam

(Printed Name)

Document2

APPENDIX 6 INDUSTRY CONTACTS

ID	Company	Phone	Fax	Address	Products current
1	Pacific Export services	0755-972727/0412-764850	0755-972727	5 Jacana St Ashmore Gold Coast Qld 4214 Aust	Shark cartilidge, becehedem, abalone gut
2	Hursey seafoods	004-581103	004-581103	2 Alexander ter stanley TAS 7331	Seafood
3	South Pacific Dried foods	07-32773533 / 0414755645	07-32773532	Unit 1/16 Brezknozk st Archerfied QLD 4108	Sharkfin, bechedemer, seadragon-Hugen Shield
4	Tainey seafoods	02-3166958/ 0418160148	02-3166962	Unit 18/32 Perry st Matraville NSW	Bechedemer & fish
5	Riba foods	02-5198213	02-5172943	43 Hutchinson St saint Peters NSW 2044	
6	Flame china	02-7487599	02-7480140	75 Parramatta Rd Silver water Sydney NSW 2128	Bechedemer, abalone, sharkfin
7	C.A. Impex	02-7421403/ 0419227529	02-7421403	Unit 6/block 14 Burlington Rd Homebush NSW	
8	Tommy Finns Smoked Trout	03-97614440/0411122794	03-97614550	F18/128 Canterbury Rd Kilsyth VIC 3137	Seafood
9	CMPS Antartic quest	03-2726752/7728539 /055-2336	055-233688		
10	Lonimar Australia	03-3765000	03-3721198		Abalone, Bechedemer,scallops
11	Pacific Shoji	03-6900777	03-96900888	117 Thistlewaite St Sth Melbourne VIC 3205	Abalone,lobster,trochus,oyster
12	K & TJI Pty Ltd	03-93376156	03-93375017	Lot 24, Thomas Rd Laverton Nrth VIC 3175	Seafood
13	Tasmanian seafoods Pty Ltd	03-97683615	03-97683616	17 Redgum dr Dandenong VIC 3175	Bechedemer, abalone, fish
14	Quotila	03-9775001	03-97750127	Factory 2/2 Aster avenue carrum downs VIC 3201	Squid & oils
15	SIGRI Nominess Pty Ltd	03-97946505	03-97065205	6 Redgum dr Dandenong VIC 3175	Fish, urchin,scallops,lobsters, abalone
16	Interon Pty Ltd	044-555136	044-552823	318 Blackburn rd Ulladulla NSW 2539	Abalone
17	Beach Gold Seafood product	07-38990402	07-38990401	2/66 Riverside place Morningside QLD 4170	Fish roes
18	*No company name yet	070-503337/ 332701	070-314472	Torres Strait QLD	
19	Qld sundried seafoods	071-268221	071-268111	MS 379 Woodgate rd Goodwood/childers QLD	Bechedemer,sharkfin,pipefish & seadrgaon
20	Seito ocean products	071-521766	071-531082	PO Box 839 Darnell st east Bunderberg QLD	Shark cartilidge & fins
21	Seagood Aust pty Ltd	075-270888	075-311988	4th Fl, 66 marine Parade Sthport QLD 4215	Sharkcartilidge
22	Hart fishereis	077-712461	077-712620	63 potts st Townsville QLD 4810	Sharkfin & seadragon
23	Wahkazi Pty Ltd	08-3327407/018830303	08-314722	29 Lincoln st kensington gardens SA 5068	fish
24	Dover fisheris	08-3412299	08-3412246	23 Wilson st Royal Pk SA 5014	Abalone, shells
25	Transglobal Marketing	08-89470588	089-470769	3302-2 Export dr Berrimah NT 0820	Sharkfin, trepang, pearl meat, fish bladder,
26	Leeuwin Star Pty Ltd	09-3093939	09-3093797	3/45 Dellamarta rd Wangara WA 6065	Abalone
27	Nor West seafoods	09-3351311 sakib		WA	Prawns coral
28	Troy Sea holdings	09-4572971	09-4572971		
29	Le Mer marketing & consultancy	015- 991626 - Joe Renkin	019-108628	Port Hedland, WA 6721 (PO Box 418)	Oysters,pearl
30	Broom Pearls	091-921295 & 922061-John Weadley	091-922597	125 Blackman st Broome WA 6725	Pearl, pearl flesh & shell
31	Australian Abalone exporters Pty	03-93144238-fred Glasbrenner	03-93146388	lot 15 Plummer rd Laverton Nrth. 3025 melbourne	abalone, carp powdered fish