Title: DRYING METHOD AND APPARATUS

Abstract: The invention relates to a method of drying a biodegradable material, such as a plant or animal product, comprising: a. Pre treating the material to reduce enzymatic degradation and / or microbial, particularly bacterial, attack; and b. Subjecting the material to drying conditions. It also relates to a process for drying oily fish, such as salmon and other pelagic species, comprising: i) Pre treating the material to reduce the oil content of the material; and ii) Subjecting the material to drying conditions. These and other drying processes are preferably conducted in a drying apparatus (10) of the invention. The closed loop drying apparatus (10) comprises a drying chamber (24) having a floor (70), a ceiling (72), two end walls (74; 76) and two side walls (78; 80). Incorporated towards the ceiling, and running substantially the whole length of the ceiling is some ducting (32). Located at one end (74) of the drying chamber (24) are two dehumidifying units (18) each comprising an expansion chamber (26), a compressor (28) and a heat exchanger (30). Mounted externally to the drying chambers are two external heat exchangers (20) which are operatively linked with the dehumidifying unit. In one embodiment ammonia is removed by diverting a proportion of the drying gas out of the drying chamber, through a scrubber and back into the closed loop apparatus. It also relates to a method of drying a food or animal product, particularly fish waste, and to the product obtained by the method.

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DRIYING METHOD AND APPARATUS

TECHNICAL FIELD

The present invention relates to a method of drying a biodegradable material, such as a plant or animal product, particularly one which will be ingested such as a food, pharmaceutical or nutraceutical product, and most particularly one with a high nitrogenous content such as fish and fish waste. It also relates to product obtained by the method and to a drying apparatus developed for use with said method, more particularly, though not exclusively, to a closed loop drying apparatus.

BACKGROUND TO THE INVENTION

The drying of solids is an important unit process in the chemical, pharmaceutical, agrochemical, cosmetic, detergent and food processing industries.

Solids are conventionally dried using one of a number of processes including:

Oven drying in which a solid is spread relatively thinly over a supporting surface, which is often heated, and the wetting solvent, often water, is removed by evaporation often under reduced pressure;

Drying in a cone drier in which a solid is tumbled through a ‘figure of eight’ motion in a double ended heated cone, usually under vacuum; and

Drying in a fluid bed drier in which a solid to be dried is agitated by suspension in a heated air stream. Fresh heated air is introduced through filters in the base of the container whilst the solid is prevented from escaping with the air stream by fabric filters. Such driers may take the form of large towers.

The foregoing methods of drying are energy inefficient and in some cases require the input of large volumes of air. Where the ingress of air is permitted or required, such air often needs to be filtered to preserve the integrity of the product. In the case of
pharmaceuticals such air filtration has to remove sub-micron particles to ensure the removal of potential pathogens, pollen and the like and is an expensive process.

However, whatever the method and apparatus, the drying of some plant and animal products can be difficult due to the fact they are prone to degradation. Products which may be consumed or ingested, e.g. food products, pharmaceuticals and nutraceuticals need to be subjected to drying under particularly stringent conditions because of the health risks associated with the contamination or degradation of such products.

Plant and animal products with a high water content often need to have water removed to avoid microbial attack, but the process of drying (which often involves an element of heating) can in itself speed the degradation process. In products rich in e.g. nitrogenous material this can be particularly troublesome and indeed the processing of fish products (including waste) is known to present processors of such products with difficulties.

The applicants have found that a product may be advantageously and efficiently dried by:

1. Using a pre treatment process prior to drying; and

2. Preferably, drying using heat pump principles, wherein the product to be dried is most preferably placed on e.g. trays in a closed chamber which may be operated at elevated or reduced pressures.

Furthermore the commercial drying of oily fish, such as salmon and other pelagic species, has to date been considered extremely difficult or impossible.

The applicant has developed a method of successfully drying such fish products.

However the pre treatment process may be used with drying processes and apparatus which do not utilise closed systems.
DISCLOSURE OF THE INVENTION

According to a first aspect of the present invention there is provided a method of drying a biodegradable material, such as a plant or animal product, comprising:

i. Pre treating the material to reduce enzymatic degradation and / or microbial, particularly bacterial, attacks; and

ii. Subjecting the material to drying conditions.

Preferably the pre-treatment step comprises soaking, washing or spraying the product with a biocide, such as, for example a hypochlorite, hydrogen peroxide or bisulphite solution or an acidulant, such as, for example, a solution of phosphoric acid, acetic acid, lactic acid, citric acid, tartaric acid, malic acid, fumaric acid, ascorbic acid, sorbic acid, glucono-delta-lactone or combinations thereof. These are particularly effective in preventing or substantially reducing the formation of ammonia and volatile amines during the drying of fish and fish waste and of course are food compatible.

Such biocides and preservatives are found to be effective at concentrations of upwards of 0.1 percent in the wash water (and up to 5%) and for immersion (or contact) times of upwards of 1 minute (and up to several hours and longer).

Additionally, or alternatively, a biocide may be introduced with the drying gas. Suitable biocides for introduction with a drying gas include ethylene oxide and ozone.

Preferably the biodegradable product is an animal product, most preferably fish or fish waste.

Preferably, though not essentially, the drying process is conducted in a closed system, and the drying gas and energy sources are recycled. In this way the apparatus is not only cheap to produce but the process is cheap to run.

According to a second aspect of the present invention there is provided a process for drying oily fish such as salmon and other pelagic species, comprising:
i) Pre treating the material to reduce the oil content of the material; and
ii) Subjecting the material to drying conditions.

In one embodiment the pre-treatment step comprises reducing the oil content using a solvent extraction, such as, for example, liquid CO2 extraction, super critical fluid extraction, alcoholic extraction, using e.g. ethanol, or other solvents, such as, for example, tetrahydrofuran and petroleum ether. Ideally the solvent is one used in the food industry.

Alternatively, an oil absorbing material might be used, such as, for example, diatomaceous earth, keiselguhr, pumice, clay, sawdust, or hydrophobic organic polymers.

This further aspect can advantageously be employed with the first aspect of the invention.

The above drying methods are advantageously conducted in a closed loop drying apparatus.

According to a third aspect of the present invention there is provided a closed loop drying apparatus comprising:

i) one or a plurality of drying chambers, in which a product to be dried is placed,
ii) a closable opening, through which the product to be dried may be brought in and out,
iii) one or a plurality of fans or other means for circulating a drying gas about the one or a plurality of drying chambers so as to dry the product therein,
iv) one or a plurality of dehumidifying units located within the one or a plurality of drying chambers and each comprising
   i) an expansion chamber;
   ii) a compressor; and
   iii) a heat exchanger;
v) one or a plurality of heat exchanger units, located externally of the one or a plurality of drying chambers, and
vi) a control unit for managing the circulation of the drying gas.

Preferably each dehumidifying unit is operationally linked with the external heat exchanger units.

Preferably the dehumidifying units use, as a refrigerant, chlorofluorocarbons, such as, Freon or liquid Ammonia.

Each drying chamber is preferably ducted and uses a fan or another means capable of circulating the drying gas, usually though not necessarily air, around the chamber. The fans are preferably mounted in the ducting approximately mid way across the drying chamber so as to encourage the drying gas to circulate from the dehumidifying unit through the ducting and back across the drying chamber to the dehumidifying unit.

The apparatus, and more particularly the drying chamber, preferably includes a sealable opening and a trap for the removal of a condensate. It also, preferably incorporates a dosing port.

In a particularly favoured embodiment, which may be independent of the first aspect of the invention, the apparatus further comprises exit and entry ports for diverting a proportion of the drying gas from each drying chamber to a scrubber and back by an associated pump means. This configuration allows noxious gases, which may be formed during the drying process, to be removed whilst maintaining energy efficiency and overcoming wet tail gas problems.

In one embodiment the apparatus comprises a plurality of drying chambers each of which may be operated independently of one another.

In a particularly favoured embodiment the drying apparatus is a mobile unit or is adapted so that it is easily mobile. Thus, in one embodiment, the apparatus takes the form of a modified (1crry or ship) container which is transportable on a trailer.
In yet another embodiment the apparatus incorporates means for smoking as well as drying products thereby enabling simultaneous or sequential drying and smoking of e.g. fish and other food products which are cured.

Preferably the fans, dehumidifying units, and external heat exchanger units are operationally linked such that the control unit manages the drying process ensuring

a) the drying gas passes over the dehumidifier’s expansion chamber and across it’s heat exchanger (such that a warm moist drying gas is dried at the expansion chamber, the resulting condensate is directed out of the drying chamber, the now cooled dried drying gas is warmed at the heat exchanger and is directed back into the drying chamber as a warm dried drying gas; and

b) one or more of any electrical driving energy, any energy recovered from the drying gas, and any latent energy gained from the dehumidification process are combined and directed to the heat exchanger of the dehumidifying unit to heat the drying gas.

Such an arrangement makes the apparatus particularly energy efficient to run.

In operation the dehumidifier contains a refrigerant which is operationally controlled to flow between the compressor, the internal heat exchanger, external heat exchanger and the expansion chamber in a refrigeration cycle in which:

i) the compressor heats the refrigerant such that it is a warm refrigerant gas and directs it to the internal heat exchanger where it warms the cool drying gas;

ii) the temperature of the internal heat exchanger is optimised by controlling the flow of the refrigerant between the internal heat exchanger and the external heat exchanger; and

iii) the refrigerant leaving the heat exchanger is cooled and becomes a pressurised liquefied refrigerant which is circulated to the expansion chamber where it is converted back to a cool refrigerant gas before being compressed for the refrigerant cycle to be repeated.

According to a fourth aspect of the present invention there is provided a method of drying a product comprising:
i) Placing the product in a closed drying chamber;

ii) Circulating a drying gas within the drying chamber whereby

   a) the drying gas passes over an expansion chamber of a
dehumidifying unit and across to a heat exchanger of the dehumidifying unit
such that a warm moist drying gas is dried at the expansion chamber, the
resulting condensate is directed out of the drying chamber, the now cooled
dried drying gas is warmed at the heat exchanger and is directed back into the
drying chamber as a warm dried drying gas; and

   b) one or more of any electrical driving energy, any energy recovered
from the drying gas and any latent energy gained from the dehumidification
process are combined and directed to the heat exchanger of the dehumidifying
unit to heat the drying gas.

In this method a refrigerant flows between a compressor, the internal heat exchanger,
an external heat exchanger and the expansion chamber in a refrigeration cycle in
which:

   i) the compressor heats the refrigerant such that it is a warm refrigerant gas
and directs it to the internal heat exchanger where it warms the cool drying gas;

   ii) the temperature of the internal heat exchanger is optimised by controlling
the flow of the refrigerant between internal heat exchanger and external heat
exchanger; and

   iii) the refrigerant leaving the heat exchanger is cooled and becomes a
pressurised liquefied refrigerant which is circulated to the expansion chamber where it
is converted back to a cool refrigerant gas before being compressed for the refrigerant
cycle to be repeated.

Preferably the temperature in the chamber is maintained at between 20 and 40°C and
a temperature differential between the cooled drying gas and the warmed drying gas is
maintained at less than 20°C, more preferably less than 10°C and more preferably still
less than 5°C by controlling the relationship between the internal and external heat
exchangers.
In a preferred method of the invention, and according to an aspect which is additionally independent thereof, a proportion of the drying gas is lead from the drying chamber, passed through a scrubber and reintroduced into the drying chamber.

Where the product being dried has a protein content rich in basic amines or amino acids with terminal amide groups, e.g. glutamine and arginine, the scrubber preferably contains a chemical for removing ammonia and optionally additionally water, such as, for example, concentrated sulphuric acid. In the drying of fish the production of ammonia is a major hazard and this aspect of the invention is particularly advantageous.

The drying gas may be air or an inert gas, such as nitrogen or carbon dioxide. Indeed in some embodiments it may be appropriate to change the drying gas during processing e.g. changing from an aerobic to an anaerobic system or vice versa.

Preferably the product to be dried is a biodegradable material, such as a plant or animal product, more particularly one to be consumed such as a food or pharmaceutical product. The animal may be a carcass (whole or part), most preferably fish or fish waste. The fish or fish waste may be a white fish e.g. Cod or other demersal fish species or an oily fish e.g. Salmon or other pelagic fish species. Also, in the case of diseased animals e.g. BSE diseased cows, diseased chickens or pigs the animal carcasses can be partially dried to allow effective and efficient incineration. The animal may also be a human.

To further overcome the problem of degradative gases, and in particular ammonia, forming during drying, a pre-treatment step (as identified with reference to the first aspect of the invention) may be included to reduce microbial, particularly bacterial, levels.

A preferred pre-treatment step comprises soaking, washing or spraying the product with a biocide, such as, for example a hypochlorite, hydrogen peroxide or bisulphite solution. Particularly effective in preventing or substantially reducing the formation of ammonia and volatile amines during the drying of fish and fish waste are food or pharmaceutical compatible biocides and preservatives with a low pH, preferably
below pH 5, such as, for example, acetic acid, lactic acid, citric acid, tartaric acid, malic acid and ascorbic acid.

Such biocides and preservatives are found to be effective at concentrations from 0.1 to 5 percent in the wash water and for immersion times varying from 1 to several hours or more.

Additionally or alternatively a biocide may be introduced with the drying gas.

Where the process is conducted in a closed system, the drying gas and energy sources are recycled so the apparatus is not only cheap to produce but is also cheap to run.

The apparatus and method of the third and forth aspects of the invention are based upon thermodynamic principles, and the system is at its most efficient when the temperature differences between the hot and cold surfaces of the heat-pump are at a minimum, typically less than 20°C, more preferably less than 10°C, and more preferably still less than 5°C. In practice drying is more rapid the greater the difference in temperature between the hot and cold surfaces of the heat-pump up to the point where the rate of drying is limited by the rate of diffusion within the solid, followed by a more rapid evaporation of the solvent from the surface of the solid to the gas stream.

Although these optimum temperature differences vary from product to product and with the thermal characteristics of the drying gas, the applicant has found that satisfactory and rapid drying can be achieved in many cases with temperature differences of as little as 10°C and sometimes as little as 5°C.

A further advantage of the invention is that there is a given, relatively small volume of gas in circulation, and its initial filtration or in-line treatment or subsequent removal for treatment is minimised.

Where the product is to be consumed, such as a food, pharmaceutical or nutraceutical product, particularly a fish waste product, it is advantageous to add a biocide to the drying gas. A preferred biocide is ethylene oxide as it will provide a sterile
atmosphere inhibiting mould and/or bacterial attack of the product undergoing drying. The ethylene oxide concentrations may be as little as 500ppm to completely inhibit biogenesis and is conveniently added and maintained in the closed loop system of drying.

A specific use for the apparatus and methods of the invention is in the drying of fish and fish waste. Thus applicant has found that fish fillets or the remaining waste consisting of head, skeleton and tail is conveniently dried at an ambient temperature from 20° to 40° C more preferably from 25° to 30° C.

The applicant has found that the drying of the fish head is greatly assisted by splitting the head beneath the jaw from front to back and pressing the head down hard against a firm surface to provide a flattened more open structure. The speed of drying, particularly with oily fish such as Salmon, can be significantly increased depending on how the fish is split.

The drying of oily fish such as Salmon and other pelagic species of fish is further significantly improved if some of the oil is first removed from the flesh by the use of solvents such as petroleum ether or liquid carbon dioxide. Additionally, or in place of the solvents, the oily fish may be placed in intimate contact with an oil absorbing material such as those used in oil spills in the petroleum industry, such as, for example, diatomaceous earth, keiselguhr, pumice or sawdust. The oil from such absorbents may be re-extracted if necessary.

The applicant has also determined that the drying of fish and fish waste is accompanied by the formation of ammonia, which concentration rapidly exceeds the levels permitted by the Health and Safety Act and creates a hazard to workers and the environment. It can also corrode the apparatus. Whilst ammonia can be removed by external scrubbers in well known and published procedures, such methods of removal provide a water-wet tail gas which may be re-introduced to the closed loop dryer to conserve thermal energy but which then would extend the time taken to dry the product.
According to a further and independent aspect of the present invention there is
provided a closed loop drying apparatus comprising:

one or a plurality of drying chambers, in which a product to be dried is placed,
and

a closable opening through which the product to be dried may be brought in
and out wherein the drying chamber comprises means for diverting a proportion of
the drying gas out of the apparatus, through a scrubber and back into the drying
chamber.

Preferably the closed loop drying apparatus further comprises:

one or a plurality of fans or other means for circulating the drying gas about
the one or a plurality of drying chambers so as to dry the product therein,

one or a plurality of dehumidifying units located within the one or a plurality
of drying chambers,

one or a plurality of heat exchanger units located external to the one or a
plurality of drying chambers, and

a control unit for managing the circulation of the drying gas.

In this aspect the scrubber is adapted to remove ammonia and or water from the
drying gas.

Preferably the scrubber is or contains concentrated (≥70%) sulphuric acid.

According to yet a further aspect of the present invention there is provided a method
for drying a plant or animal product comprising:

i) drying the plant or animal product by passing a drying gas over the plant or
animal product in a closed system,

ii) diverting a proportion of the drying gas from the closed system and passing

it through a scrubber to remove a noxious gas from the drying gas, and

iii) reintroducing the drying gas back into the closed system.

The applicant has determined that the ammonia produced may be eliminated, as it is
formed, by providing an in-line scrubber containing sulphuric acid. The sulphuric
acid so used is preferably between 50% and 100% in strength. Advantageously, greater than 90% strength sulphuric acid is used at the start of the drying process as this also assists in the initial drying of the gas. As drying proceeds, the sulphuric acid undergoes dilution and eventually reaches equilibrium with the moisture content of the gas effecting the removal of water from the plant or animal product.

These changes in the water content of the sulphuric acid do not impair the ammonia removing capability of the sulphuric acid.

The applicant has found that whilst a closed loop system is the preferred method of drying fish and fish waste, the pre-treatment aspects of the invention are also effective when drying fish or fish waste in non-closed systems such as tunnel dryers and other systems open to the atmosphere.

The drying of fish or fish waste in accordance with this invention provides a highly nutritious sterile product with excellent storage properties showing little or no denaturing of the protein content and is much sought after by African and other developing nations.

According to yet a further aspect of the present invention there is provided a nutritious fish product obtained by drying fish waste according to the methods of the invention.

**BRIEF DESCRIPTION OF FIGURES**

The various aspects of the invention are further described, by way of example, with reference to the following figures and examples in which:

Fig 1 is a schematic representation illustrating the principle of operation of an apparatus according to a first aspect of the invention;

Fig 2 is a representation of a first embodiment of an apparatus of the invention shown by way of end and side elevations and in plan; and
Fig 3 is a representation of a second embodiment of an apparatus of the invention shown by way of end and side elevations and in plan.

BEST MODES FOR CARRYING OUT THE INVENTION

Example 1.
A method of drying demersal fish including a pre-treatment step according to a first aspect of the invention.

A fresh cod head weighing 909 g was washed in clean water and allowed to drain. The lower jaw was then cut through the lip with a pair of scissors and the head split open by pressing it down on a firm base. Two further cuts were made longitudinally from front to back and through the roof of the mouth, each either side of the vertebrae and inclined to each other and subtending an angle of about 60 degrees at the exposed vertebra column. The cuts were made to penetrate into the flesh of the carcase but terminate about 1 cm from the skin surface. Care was taken not to lacerate the eye.

The lacerated head was then totally immersed in a 1% w/v solution of citric acid monohydrate (food grade) and agitated from time to time over a period of one hour. The head was then removed from the solution, drained briefly and then placed on a wire tray in the closed loop dryer of the invention.

The dryer was then operated at a drying gas temperature of 27° to 29° Celsius for 72 hours during which time a total of 709 g of water was collected.

The resulting dried cod head, which now weighed 200 g consisted of 65 g bone and cartilage (32.5% w/w) and 135 g of dry protein (67.5% w/w).

No ammonia was produced at any stage of the process and the product showed excellent storage properties.

Example 2.
A method of drying pelagic fish including a pre-treatment step according to a first aspect of the invention and the isolation of oil there from.

Six salmon heads weighing a total of 2,520 g were washed, split and lacerated as in example 1 and then covered with 2.5 litre of a 2% w/v solution of citric acid
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monohydrate (food grade) for a period of 45 minutes. The salmon heads, now lighter
in colour, were removed from the solution, drained for a few minutes and then placed
on their backs on wire trays and placed in the closed loop dryer of the invention.

The dryer was then operated at a drying gas temperature of 29° to 32° Celsius for 120
hours during which time a total of 1,420 g of water was collected.

The resulting six dried salmon heads, which now weighed 1,100 g were put through a
filter press to give 314 g of a deep straw coloured oil.

The residual pressed cake, now weighing 786 g was further extracted with two, 1 litre
lots of hot 90% isopropanol to yield a further 65 g of oil and 149 g of low molecular
weight protein.

The final 572 g of biscuit coloured residue consisted of a floculent mixture of bone,
cartilage and higher molecular weight protein.

No ammonia was produced at any stage of the process.

Example 3.

A method of drying a plant product including a pre-treatment step according to a first
aspect of the invention.

One kilo of freshly washed spinach leaves was shaken free of surplus water and
immersed in a 0.25% solution of sodium metabisulphite for 15 minutes. The spinach
leaves were removed from the solution and placed in the closed loop dryer of the
invention. The air in the dryer was displaced by nitrogen to give essentially an
anaerobic atmosphere and drying effected at a temperature of 25° to 35° Celsius until
the production of water had essentially ceased. Air was introduced to the dryer and
after one days further drying at 35° Celsius there was removed from the dryer 200 g
of brown dried spinach free from any sign of microbial attack.

Example 4.

A method of drying oily fish including a pre-treatment step according to a second
aspect of the invention.

Two salmon heads weighing a total of 840 g were cut in to pieces of about 1 cm cube
or less and placed in the thimble of a Soxhlet Extractor. Boiling 60/80 petroleum
ether was used in the apparatus and after 24 hours of extraction there was removed 145 g of oil, which was readily recovered by evaporation of the solvent.

The residual, partially de-oiled product was then immersed in a 0.5 % w/v ascorbic acid solution for a period of 2 hours, removed, drained and placed on trays in the closed loop dryer of the invention.

The dryer was then operated at a drying gas temperature of 27° to 33 ° Celsius for 72 hours during which time a total of 480 grm of water was collected.

The dried product had a good shelf life and was readily re-constituted with water 12 weeks later to form the basis of a flavoursome soup.

No ammonia was produced at any stage of the drying process.

Example 5.

Description of preferred closed loop drying apparatus and principles of operation.

Fig 1 illustrates the principle of operation behind one aspect of the invention.

The apparatus functions on heat pump principles, namely:

- For a liquid to evaporate into a gas it must absorb heat.
- For a gas to return to a liquid it must give up the heat absorbed.

Evaporation can be effected by reducing the pressure of the liquid, whereon it absorbs heat from itself and its surroundings becoming cool in the process.

Conversion of a gas to a liquid can be effected by increasing the pressure, whereon it gives out heat becoming warm in the process.

Thus, referring to Fig 1 the de-humidifier (18), which is a simple heat pump, consists of a compressor (28), a heat exchanger (30) and an expansion chamber/chiller (26) connected in a loop, filled with Freon or another refrigerant (46), which circulates from one to the other in the foregoing order.

In operation, the compressor (28) compresses the gaseous Freon (46), which becomes hot (46a) in the process.
The hot pressurised gaseous Freon (46a) passes to the heat Exchanger (30), which heats the cold dry air (16c) flowing over it and returns hot dry air (16d) to the drying chamber (24).

The heat exchanger (30) which is within the body of the dehumidifying unit (18) is linked to an external heat exchanger (20), which removes surplus heat by air cooling (60). (Hence it is external to the drying chamber).

The pressurised Freon (46b) undergoes cooling in heat exchangers (30 and 20) and condenses to a liquid whilst still under pressure.

The pressurised liquid Freon (46c), now at ambient temperature is allowed to expand into the expansion chamber/chiller (26) causing it to cool rapidly as the pressure drops.

The warm humid air (16a) from the drying chamber (24) passes over the surface of the expansion chamber/chiller (26), dropping in temperature and precipitating the moisture in the air as droplets, which condensate (16b) is sent to waste via a trap (62) in the floor of the drying chamber (24).

The cold dry air (16c) leaving the surface of the expansion chamber/chiller is warmed to about 30°C by the heat exchanger (30) and the resulting warm dry air (16d) re-enters the drying chamber (24) to pick up further moisture from the product e.g. fish being dried.

The cold Freon gas (46d) exiting the expansion chamber/chiller (26) is returned to the compressor (28) and the whole cycle is repeated until the requisite amount of water condensate has been removed.

In operation as a fish drier, the drying chamber (24) and contents (typically 10 tons of wet fish or fish by-products) are preheated to about 30°C. The 10 tons of wet fish represents about 2.5 tons of dry fish and 7.5 tons of water now at 30°C.
Consequently, to dry the fish, one has to convert 7.5 tons of water at 30°C to 7.5 tons of water at about 18°C and discharge this from the condensate trap.

A further improvement in energy conservation can be effected by using the heat ‘pumped’ out through the external heat exchanger (20) to raise the temperature of the next batch of fish to the initially required temperature of about 30°C.

Referring to Figs 2 the representation shows a closed loop drying apparatus in end elevation, side elevation and plan. The closed loop drying apparatus (10) comprises a drying chamber (24) (side elevation) having a floor (70), a ceiling (72), two end walls (74; 76) and two side walls (78; 80) (see plan). Incorporated towards the ceiling, and running substantially the whole length of the ceiling is some ducting (32). Located at one end (74) of the drying chamber (24) are two dehumidifying units (18) (plan) each comprising an expansion chamber (26), a compressor (28) and a heat exchanger (30) (Compare to Fig 1). Mounted externally to the drying chambers two external heat exchangers (20) (end elevation) are operatively linked with the dehumidifying units as Fig 1.

Access to the drying chamber (24) is gained through sealable loading doors (12). (plan). In use, as noted with reference to Fig 1 the drying gas (16), most commonly air is caused to circulate in the drying chamber (24) by a plurality of fans (14) (plan) suspended in ducting 32 (side elevation). The fans are positioned about midway along the length of the drying chamber and draw dry warm air (16d) from the heat exchanger (30) of the dehumidifier (18) along the ducting to the end wall (76) remote from the end wall (74) against which the dehumidifying units (18) are positioned. The dry warm air then returns back towards the dehumidifying units picking up moisture from the product (48) which is typically placed on trays on trolleys within the drying chamber (24). The now warm moist air (16a) hits the expansion chamber (26) where it cools and condensate (16b) is collected and removed through trap (62) (side elevation).

Fig 3 is in many ways similar to Fig 2 but illustrates a closed loop drying apparatus built within a ships container. It comprises a single dehumidifier (18) and external heat exchanger (20). It additionally shows how an apparatus may be adapted in accordance with the fifth aspect of the invention whereby an exit port (36) is able to
divert a portion of the drying gas (16) out of the drying chamber, through a scrubber (40) containing concentrated sulphuric acid to remove ammonia and water and feed the drying gas back into the drying chamber via entry port (38). A pump (42) provides the means to drive the drying gas. In addition it incorporates a dosing port (34) via which a biocide may be added and a smoker (44). Otherwise like numbers are used to identify like parts.

Due to the unique nature of e.g. a Calorex® refrigeration circuit, energy removed from the air during the dehumidification process is converted into useable heat. Typically, for every 1kW of electrical energy that the dehumidifier consumes, it will give out 2.5kW of heat energy. Thus by removing moisture from the air, rather than heating it to a high temperature, drying occurs in a gentle, more controllable manner. This process also results in a substantial saving in running costs.

The apparatus illustrated in Fig 3 is one example only of an apparatus modifiable according to the fifth aspect of the invention. In this aspect this or another closed system drying apparatus may be modified by ensuring a proportion of the gas exits the apparatus, passes through a scrubber of e.g. concentrated sulphuric acid to remove ammonia which builds up in the apparatus when protein rich products such as fish waste are dried, and is reintroduced to the apparatus. The proportion of the gas diverted through the scrubber (40) will vary from product to product and during any one drying cycle, from one change of air per hour to one change per 10 hours or even none at all. This recirculation overcomes wet tail gas issues.

A fish product obtained by the method of the invention is characterised in that it has a specification of:

- **TVC-aerobes** $<5 \times 10^9$ cfu per grm
- Presumptive entero-bacteriaceae $<1 \times 10^2$ cfu per grm
- **E. Coli** $<10$ cfu per grm
- **Staphylococcus** $<10$ cfu per grm
- **Salmonella** absent in a 25 grm sample
- **Vibrio parahaemolyticus** absent in a 25 grm sample
- Sulphite reducing Clostridia $<10$ cfu per grm
- pH $7.0 - 8.0$
- Water activity $<0.86$ Aw
- Protein Content $60 - 75\%$. 
CLAIMS

1. A method of drying a biodegradable material, such as a plant or animal product, comprising:
   i) Pre treating the material to reduce enzymatic degradation and/or microbial, particularly bacterial, attack; and
   ii) Subjecting the material to drying conditions.

2. A method of drying a biodegradable material as claimed in claim 1 wherein the pre-treatment step comprises soaking, washing or spraying the product with a biocide.

3. A method as claimed in claim 2 wherein the biocide is selected from: a hypochlorite, hydrogen peroxide, a bisulphite solution and an acidulant.

4. A method as claimed in claim 3 wherein the acidulant is selected from: a solution of phosphoric acid, acetic acid, lactic acid, citric acid, tartaric acid, malic acid, fumaric acid, ascorbic acid, sorbic acid, glucono-delta-lactone or combinations thereof.

5. A method of drying a biodegradable material as claimed in any of the preceding claims wherein the material is capable of generating ammonia and volatile amines during drying.

6. A method as claimed in any of the preceding claims wherein the material which is fish or fish waste.

7. A method as claimed in any of the preceding claims in which the biocide is used at concentrations of from 0.1 percent in wash water and for an immersion (contact) time of from 1 minute.

8. A method as claimed in any of the preceding claims in which drying is conducted in the presence of a drying gas.
9. A method as claimed in claim 8 wherein the drying gas is circulated in a closed system.

10. A method as claimed in claim 8 or 9 wherein the drying gas is air.

11. A method as claimed in any of claims 8 to 10 wherein a biocide is introduced with the drying gas.

12. A method as claimed in claim 11 wherein the biocide for introduction with a drying gas is ethylene oxide or ozone.

13. A method as claimed in any of claims 9 to 12 in which the drying gas is recycled in a closed loop drying apparatus.

14. A method as claimed in any of the preceding claims further comprising a step to reduce the oil content of the material.

15. A process for drying oily fish, such as salmon and other pelagic species, comprising:

   i) Pre treating the material to reduce the oil content of the material; and

   ii) Subjecting the material to drying conditions.

16. A process as claimed in claim 15 wherein the pre-treatment step comprises reducing the oil content using a solvent extraction.

17. A process as claimed in claim 16 wherein the solvent extraction is selected from: a liquid CO2 extraction, a super critical fluid extraction, an alcoholic extraction, and an extraction with tetrahydrofuran or petroleum ether.

18. A process as claimed in claim 15 wherein the pre-treatment step comprises contacting the fish with an oil absorbing material.
19. A process as claimed in claim 18 wherein the oil absorbing material is selected from: diatomaceous earth, keiselguhr, pumice, clay, sawdust, and hydrophobic organic polymers.

20. A closed loop drying apparatus (10) comprising:
   i) one or a plurality of drying chambers (24), in which a product (48) to be dried is placed,
   ii) a closable opening (12), through which the product (48) to be dried may be brought in and out, 
   iii) one or a plurality of fans (14) or other air moving means for circulating a drying gas (16) about the one or a plurality of drying chambers so as to dry the product therein, 
   iv) one or a plurality of dehumidifying units (18), each comprising
       a) an expansion chamber (26); 
       b) a compressor (28); and 
       c) a heat exchanger (30), located within the one or a plurality of drying chambers (24),
   v) one or a plurality of heat exchanger units (20), located external to the one or a plurality of drying chambers (24), and 
   vi) a control unit (8) for managing the circulation of the drying gas.

21. A closed loop drying apparatus as claimed in claim 20 wherein the one or a plurality of fans (14) or other means for circulating the drying gas (16) are positioned within the one or a plurality of drying chambers (24).

22. A closed loop drying apparatus as claimed in claim 20 or 21 which contains as a refrigerant, a flurochlorocarbon or liquid ammonia.

23. A closed loop drying apparatus as claimed in any of claims 20 to 22 wherein each dehumidifying unit (18) is operationally linked with an external heat exchanger unit (20).

24. A closed system drying apparatus as claimed in any of claims 20 to 23 having ducting (32) in which the fans (14) are mounted.
25. A closed loop drying apparatus as claimed in claim 24 wherein the fans (14) are mounted approximately midway across the drying chamber (24) so as to encourage the drying gas (16) to circulate from the dehumidifying unit (18), through the ducting (32) and back across the drying chamber (24) to the dehumidifying unit (18).

26. A closed loop drying apparatus as claimed in any of claims 20 to 25 wherein the closable opening (12) is a sealable opening.

27. A closed loop drying apparatus as claimed in any of claims 20 to 26 having a trap (62) in the drying chamber (24) for the removal of a condensate.

28. A closed loop drying apparatus as claimed in any of claims 20 to 27 further comprising a dosing port (34).

29. A closed loop drying apparatus as claimed in any of claims 20 to 28 further comprising exit (36) and entry ports (38) for diverting a proportion of the drying gas from each drying chamber to a scrubber (40) and back by an associated pump means (42).

30. A closed loop drying apparatus as claimed in any of claims 20 to 29 comprising a plurality of drying chambers (24).

31. A closed loop drying apparatus as claimed in claims 20 to 30 wherein each drying chamber can operate independently of one another.

32. A closed loop drying apparatus as claimed in any of claims 20 to 31 which is a mobile unit.

33. A closed loop drying apparatus as claimed in any of claims 20 to 32 further comprising smoking means (44) thereby enabling simultaneous or sequential drying and smoking of the product.
34. A closed loop drying apparatus as claimed in any of claims 20 to 33 wherein the fan (14), dehumidifying unit (18), and external heat exchanger unit (20) are operationally linked such that the control unit (8) manages the drying process ensuring

a) the drying gas (16) passes over the dehumidifier’s expansion chamber (26) and across it’s heat exchanger (30) such that a warm moist drying gas (16a) is dried at the expansion chamber (26), the resulting condensate (16b) is directed out of the drying chamber (24), the now cooled dried drying gas (16c) is warmed at the heat exchanger (30) and is directed back into the drying chamber (24) as a warm dried
drying gas (16d); and
b) one or more of any electrical driving energy, any energy recovered from the drying gas and any latent energy gained from the dehumidification process are combined and directed to the heat exchanger (30) of the dehumidifying unit (18) to heat the drying gas (16);

35. A closed loop drying apparatus as claimed in claim 34 wherein the dehumidifying unit (18) contains a refrigerant (46) which is operationally controlled to flow between the compressor (28), the internal heat exchanger (30), external heat exchanger (20) and the expansion chamber (26) in a refrigeration cycle in which:

i) the compressor (28) heats the refrigerant such that it is a warm refrigerant
gas (46a) and directs it to the internal heat exchanger (30) where it warms the cool
drying gas (16c);

ii) the temperature of the internal heat exchanger (30) is optimised by controlling the flow of the refrigerant (46b) between internal heat exchanger (30) and
external heat exchanger (20); and

iii) the refrigerant leaving the heat exchanger (30) is cooled and becomes a
pressurised liquefied refrigerant (46c) which is circulated to the expansion chamber
(26) where it is converted back to a cool refrigerant gas (46d) before being
compressed for the refrigerant cycle to be repeated.

36. A method of drying a product (48) comprising:

i) placing the product (48) in a closed drying chamber (24);

ii) circulating a drying gas (16) within the drying chamber (24) whereby
a) the drying gas (16) passes over an expansion chamber (26) of a dehumidifying unit (18) and across to a heat exchanger (30) of the dehumidifying unit (18) such that a warm moist drying gas (16a) is dried at the expansion chamber (26), the resulting condensate (16b) is directed out of the drying chamber (24), the now cooled dried drying gas (16c) is warmed at the heat exchanger (30) and is directed back into the drying chamber (24) as a warm dried drying gas (16d); and

b) one or more of any electrical driving energy, any energy recovered from the drying gas and any latent energy gained from the dehumidification process are combined and directed to the heat exchanger (30) of the dehumidifying unit (18) to heat the drying gas (16).

37. A method as claimed in claim 36 in which a refrigerant (46) flows between a compressor (28), the internal heat exchanger (30), an external heat exchanger (20) and the expansion chamber (26) in a refrigeration cycle in which:

i) the compressor (28) heats the refrigerant such that it is a warm refrigerant gas (46a) and directs it to the internal heat exchanger (30) where it warms the cool drying gas (16c);

ii) the temperature of the internal heat exchanger (30) is optimised by controlling the flow of the refrigerant (46b) between internal heat exchanger (30) and external heat exchanger (20); and

iii) the refrigerant leaving the heat exchanger (30) is cooled and becomes a pressurised liquefied refrigerant (46c) which is circulated to the expansion chamber (26) where it is converted back to a cool refrigerant gas (46d) before being compressed for the refrigerant cycle to be repeated.

38. A method as claimed in claim 36 or 37 wherein the temperature in the chamber is maintained at between 20 and 40°C.

39. A method as claimed in claim 38 wherein a temperature differential between the cooled drying gas (16c) and the warmed drying gas (16d) is less than 20°C, more preferably less than 10°C.
40. A method as claimed in any of claims 36 to 39 wherein a proportion of the drying gas (16) is lead from the drying chamber (24), passed through a scrubber (40) and reintroduced into the drying chamber (24).

41. A method as claimed in claims 40 wherein the scrubber contains a chemical for removing ammonia and/or water, for example, concentrated sulphuric acid.

42. A method as claimed in any of claims 36 to 41 wherein the drying gas is air.

43. A method as claimed in any of claims 36 to 41 wherein the drying gas is an inert gas.

44. A method as claimed in any of claims 36 to 43 wherein the drying gas is under a partial vacuum.

45. A method as claimed in any of claims 36 to 44 wherein the product is an animal or plant product.

46. A method as claimed in any of claims 36 to 45 wherein the product is an animal carcass (whole or part), particularly fish or fish waste.

47. A method as claimed in any of claims 36 to 46 in which the product is subjected to a pre-treatment step to reduce enzymatic degradation and/or microbial, particularly bacterial, attack.

48. A method as claimed in claim 47 wherein the pre-treatment step comprises soaking, washing or spraying the product with a biocide.

49. A method as claimed in any of claims 36 to 48 in which the product is subjected to a pre-treatment step to reduce the oil content of the product.

50. A method as claimed in claim 49 wherein the pre-treatment step comprises reducing the oil content using a solvent extraction.
51. A method as claimed in claim 49 wherein the pre-treatment step comprises contacting the product with an oil absorbing material.

52. A closed loop drying apparatus (10) comprising:

one or a plurality of drying chambers (24), in which a product to be dried is placed, and

a closable opening (12) through which the product to be dried may be brought in and out and wherein the drying chamber (24) comprises means (36, 38; 42) for diverting a proportion of the drying gas out of the apparatus, through a scrubber (40) and back into the drying chamber.

53. A closed loop drying apparatus as claimed in claim 52 further comprising

one or a plurality of fans (14) or other means for circulating the drying gas (16) about the one or a plurality of drying chambers (24) so as to dry the product therein, one or a plurality of dehumidifying units (18) located within the one or a plurality of drying chambers,

one or a plurality of heat exchanger units (20) located external to the one or a plurality of drying chambers (24), and

a control unit (8) for managing the circulation of the drying gas.

54. A closed loop drying apparatus as claimed in claim 53 wherein:

the fans (14), dehumidifying units (18), and external heat exchanger units (20) are operationally linked such that the control unit (8) manages the drying process ensuring

a) the drying gas (16) passes through the dehumidifier’s expansion chamber (26) and across its heat exchanger (30) such that a warm moist drying gas (16a) is dried at the expansion chamber (26), the resulting condensate (16b) is directed out of the drying chamber (24), the now cooled dried drying gas (16c) is warmed at the heat exchanger (30) and is directed back into the drying chamber (24) as a warm dried
drying gas (16d); and

b) one or more of any electrical driving energy, any energy recovered from the drying gas and any latent energy gained from the dehumidification process are combined and directed to the heat exchanger (30) of the dehumidifying unit (18) to heat the drying gas (16).
55. A closed loop drying apparatus as claimed in any of claims 52 to 54 wherein the scrubber is adapted to remove ammonia and or water from the drying gas.

56. A closed loop drying apparatus as claimed in claim 55 wherein the scrubber is or contains concentrated (≥70%) sulphuric acid.

57. A closed loop drying apparatus as claimed in any of claims 52 to 56 further comprising a means (62) for removing condensed water (16b).

58. A closed loop drying apparatus as claimed in claim 57 wherein the means (62) is a trap in a floor of the drying chamber.

59. A closed loop drying apparatus as claimed in any of claims 52 to 58 further comprising means for monitoring and controlling one or more of: temperature, drying gas flow, gas pressure, noxious gas levels, and humidity.

60. A method for drying a plant or animal product comprising:
   i) drying the plant or animal product by passing a drying gas over the plant or animal product in a closed system,
   ii) diverting a proportion of the drying gas from the closed system and passing it through a scrubber to remove a noxious gas from the drying gas, and
   iii) reintroducing the drying gas back into the closed system.

61. A method as claimed in claim 60 which is a continuous or intermittent process.

62. A method as claimed in claim 60 or 61 in which the noxious gas is ammonia and the scrubber is concentrated sulphuric acid.

63. A method as claimed in any of claims 60 to 62 wherein the drying gas is air.

64. A method as claimed in any of claims 60 to 63 wherein the drying gas is an inert gas.
65. A method as claimed in any of claims 60 to 64 wherein the animal product is fish or fish waste.

66. A method as claimed in any of claims 60 to 65 in which the animal or plant product is pre-treated to reduce enzymatic degradation and/or microbial, particularly bacterial, attack.

67. A method as claimed in claim 66 wherein the pre-treatment comprises soaking, washing or spraying the product with a biocide.

68. A method as claimed in any of claim 60 to 67 wherein the drying gas is cycled by passing it over the dehumidifiers expansion chamber (26) and across its heat exchanger (30) such that a warm moist drying gas (16a) is dried at the expansion chamber (26), the resulting condensate (16b) is directed out of the drying chamber (24), and the now cooled dried drying gas (16c) is warmed at the heat exchanger (30) and is directed back into the drying chamber (24) as a warm dried drying gas (16d).

69. A method as claimed in any of claims 60 to 68 wherein the drying process is conducted at between 20 and 40°C.

70. A method as claimed in any of claims 60 to 69 wherein the method employs a temperature differential of less than 20°C, more preferably less than 20°C, and more preferably less than 10°C.

71. A nutritious fish product obtained by drying fish waste using a method as claimed in any of claims 1 to 14, 36 to 51 or 60 to 70 or a process as claimed in any of claims 15 to 19.

72. A nutritious fish product as claimed in claim 71 characterised in that it has a specification of:

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<tr>
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<td><strong>Presumptive entero-bacteriae</strong></td>
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