

HEAT EXCHANGER FOR COOKING APPARATUS

Field of the Invention

This invention relates to heat exchangers, suitable for heating cooking media used in cooking apparatus and to further cooking apparatus and methods of heating cooking media in such cooking apparatus involving such heat exchangers.

Background to the Invention

In the Applicant's International Patent Application No. WO 93/24040 there is described a cooking apparatus operating on the spray frying principle. That is, food items are cooked by spraying them with a heated stream of cooking medium, particularly an oil or melted fat, a heat sensitive material. The cooking medium is heated by a flow heater located in a pipe network communicating a buffer or storage tank for cooking medium with sprayers. Heating occurs in the substantial absence of air and the "pipe like" nature of the heat exchanger allows effective mixing and more uniform heating than heat exchangers previously employed.

For example, there is known from the prior art, as exemplified by British Patent No. 621821 and European Patent No. 168359, a spray frying apparatus in which cooking medium is heated by a heating element located in, or sufficiently proximate to, to ensure heating in a sump or tank vessel referred to as a boiler in the presence of oxidising gas, air. Such a heating mechanism has been discovered by the Applicant not to be appropriate for heat sensitive, oxidisable cooking media and quite apart from the problem of oxidation, efficient control over the heating process is not readily achieved, overheating and excessive consumption of cooking oils has been shown to result from such heating systems. Nevertheless, such systems - which include the vat fryers so widely used in the quickservice food industry - are widely used in practice.

Such heat exchange is to be contrasted with that employed in the Applicant's International Patent Application No. WO 93/24040 in which heating occurs in a flow heater, having a well mixed volume, in the substantial absence of air with advantage in terms of product food quality and reduced oil consumption.

Some other kinds of heat exchanger are known as described below.

WO 86/05578 is a heat exchanger used to utilise heat from a motor vehicle engine cooling system for water heating or the like. The heat exchanger is designed to accommodate relatively low volumes of fluid at relatively low
5 temperatures and may be suitable as a hot water source for showers.

WO 88/01362 is a counter-current heat exchanger having several helical banks of tubes, each bank containing ten tubes and resting freely on helically arranged supporting arms.

In neither case is any reference made to heating of cooking media in
10 cooking apparatus, a heating process that involves heating of cooking medium to temperatures in excess of 150°C, more typically in the range 180°C to 210°C, nor are particular problems encountered in heating of cooking media addressed by these documents.

Summary of the Invention

15 It is the object of the present invention to provide heat exchangers for cooking apparatus, cooking apparatus and methods of heating of cooking media in such cooking apparatus involving such heat exchangers.

It is a further object to provide equipment for heat transfer to, especially heat sensitive, cooking media - such as oils and fats - which allow more efficient
20 control over the heating process than possible using the heat exchangers currently employed in the cooking art.

With this object in view, the present invention provides a heat exchanger for heating a cooking medium comprising a housing; a cooking medium chamber located in the housing for passage of cooking medium therethrough;
25 and a heat exchange element formed as a coil to define a generally spiral path for the cooking medium to pass through the cooking medium chamber during the heat exchange process. Typically, the process involves heating of cooking medium for delivery to the cooking zone of a cooking apparatus.

In particular, the heat exchange element or coil, which may take the form
30 of a single or double helix, is located in the cooking medium chamber such that there is a small clearance between it and an inner wall of the housing to confine cooking medium passing through the cooking medium chamber to a generally

spiral path. The term "spiral path" where used herein includes a tortuous helical, serpentine or like flow path which allows intimate contact of the cooking medium in a well mixed volume with the heat exchange element. In this way, a high heat transfer area may be achieved in a small volume and more efficient control over the heat exchange process may thereby be achieved without creation of major space constraints.

The heating element may be of resistive electrical type but the nature of the heat exchange element is of less importance than its design to force cooking medium travel through a carefully defined spiral, tortuous or serpentine path.

10 Heating by gas or thermal oils is possible.

The heating element may be energisable in pulse wise manner at a desired power level, the pulse width being modulated by a control unit supervising the operation of the heat exchange, particularly where an electrical element is used. This presents less risk of degradation of cooking medium.

15 Heat sensitive cooking media may be more efficiently heated in this manner.

Conveniently, the frequency of pulses is selected such that the thermal inertia of the heat exchanger element rectifies the pulses. That is, for a given power level, the power density at the heat exchange surface of the heat exchanger element will not fluctuate but will remain substantially constant.

20 The heat exchanger is designed for inclusion in cooking apparatus so, in a second aspect of the present invention, there is provided a cooking apparatus comprising a housing and a cooking zone, the cooking zone being supplied with cooking medium heated to desired cooking temperature by heat exchange means including at least one heat exchanger comprising a housing, a cooking medium chamber in the housing for passage of cooking medium therethrough during the heat exchange process and a heat exchange element formed as a coil to define a generally spiral path for the cooking medium to pass through the fluid chamber during the heat exchange process.

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Such a heat exchanger may be used in a variety of spray cooking apparatus as developed by the applicant. In particular, the heat exchanger may be employed in the spray fryer of Patent Application No. WO 93/24040 or in a unit more suitable for domestic or retail food outlet settings.

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The heat exchanger may also be employed in cooking apparatus of other kinds such as vat and pressure cookers. The cooker may be of multi-zone type. Conveniently, cooking media are heated by heat exchanger means that may take the form of modules containing a plurality of heat exchangers of the kind
5 above described. Each heat exchanger may have the same or different maximum power output. In this manner, heat output per heat exchanger may be reduced for a given cooking medium setpoint temperature which may be advantageous to maintenance of acceptable cooking medium quality, particularly where such cooking mediums are heat sensitive oils or fats.

10 In a third advantageous embodiment of the present invention there is provided a method of heating a cooking medium for cooking of food items, preferably in the substantial absence of oxidising gases such as air, comprising introducing cooking medium to a chamber of a heat exchanger; causing the cooking medium to flow in a generally spiral path formed by a heating element
15 coil located within the chamber; and heating the cooking medium to a desired temperature for cooking.

Conveniently, and advantageously, the heating element is energised in a pulsed manner, the pulse width being modulated in a controlled manner. Such pulse width modulation allows heat sensitive media to be heated with less risk
20 of degradation.

Though the heat exchange process envisaged is typically a heating process, allowing heating of a cooking medium to a cooking temperature prior to spraying of the so heated cooking medium onto food items located in the cooking chamber of a spray fryer, the heat exchanger could equally be
25 designed for cooling of fluids.

The heat exchange process advantageously takes place in the substantial absence of air in the case of heating of cooking media for spray frying apparatus as quality of cooking media and product food items may be detrimentally affected otherwise.

30 The heat exchanger, cooking apparatus and method of operation of the heat exchanger allows more efficient heating of cooking media, particularly where such are heat sensitive, than previous methods herein described.

Description of the Drawings

The invention will be more fully understood from the following description of a preferred embodiment thereof made with reference to the accompanying drawings in which:

5 Figure 1 is a perspective cut away view of the heat exchanger in accordance with one embodiment of the present invention;

Figure 2 is a side sectional view of the heat exchanger in accordance with the embodiment shown in Figure 1;

Figure 3 is a front elevation view (showing the inside) of a cooking
10 apparatus in which the heat exchanger of the present invention may be employed;

Figure 4 is a side view of a heat exchange element for use in accordance with the heat exchanger shown in Figures 1 to 3;

Figure 5 is a cross section through the heat exchanger element of Figures
15 1, 2 and 4;

Figure 6 is a diagram showing the pulse width modulation control of the heat exchanger element of Figure 4 in accordance with the present invention; and

Figure 7 is a diagram showing energisation of the heat exchange
20 element of Figures 4 and 5 at 50% power level (a), the power density in the insulator of the element (b) and the power density at the surface of the heat exchanger element (c).

Detailed Description of the Invention

Referring now to Figures 1 and 2, there is shown a heat exchanger 10
25 comprising a generally cylindrical housing 12, a cooking medium chamber 14 in the housing 12 for passage of cooking medium therethrough during the heat exchange process and a heat exchange element 16 formed to define a generally spiral flow path for cooking medium through the fluid chamber 14 during the heat exchange process. Each component is manufactured of a
30 suitable material for its function and environment, taking into account the application in which the heat exchanger is used. Therefore, the housing 12 of the heat exchanger 10 may be fabricated from stainless steel or a material

which is inert to the cooking medium with which heat is being exchanged. The heat exchanger element 16 may be manufactured from a nickel alloy such as "incone". Further description of such alloys is provided in texts such as Perry et al, Chemical Engineer's Handbook.

5 In the embodiment shown, the heat exchange element 16 is formed in the shape of a helical coil or helix having a plurality of tubular coils 16a positioned in the cooking medium chamber 14 so that cooking medium entering the inlet cooking medium chamber 21 through inlet nozzle 20 at the bottom of the heat exchanger 10, as shown, is directed through a port formed by a space between
10 coils 16b contiguous the inlet fluid chamber 21 to flow through a generally spiral flow path which has the benefit of providing a high heat transfer surface area relative to the volume of the cooking medium chamber 14 and ensuring uniform mixing of fluid and uniform heating.

The heat exchange element 16, conveniently shown in Figure 4, is
15 formed in the shape of a double helix so that electrical connections may be made at one end of the heat exchanger 10. The pitch and spacing 17 of each coil 16a is selected to achieve the desired heat transfer path length and the desired cross sectional area of the cooking medium flow path within the heat exchanger 10. The pitch is advantageously selected to be no less, and
20 preferably larger, than the heating element 16 tube diameter. The pitch may be square or angular, an angular pitch allowing a greater heat transfer area for a given length of cooking medium chamber 14.

At the end of the heat transfer path, the cooking medium exits through a port formed by the space between coils 16c contiguous a cooking medium outlet
25 chamber 70 provided with an outlet nozzle 80 allowing cooking medium to pass to downstream process units, notably the cooking zone of cooking apparatus. Outlet nozzle 80 is to be located at the highest position in chamber 70 and heat exchanger 10 so that no air is trapped inside. It is considered that an air bleed valve may be used but as the amount of air dissolved in cooking medium may
30 vary with temperature this may not be acceptable as air separation and air pocket formation within the heat exchanger 10 could cause overheating at the pocket(s). To achieve this flow path, the heat exchange element 16 is

conveniently arranged about a spacer 40 located in the housing 12 of the heat exchanger 10, the housing and spacer 40 defining the chamber 14. The spacer 40, as with the housing 12, is of generally cylindrical construction and there is sufficient clearance between the inner wall 12a of the housing and the heat exchange element 16 to enable it to be located by sliding into the housing 12 but not sufficient to compromise the desired generally spiral flow path. The spacer 40 may be of metal or ceramic or other suitable material tolerant to the high temperatures typically encountered when the heat exchanger 10 is in operation as a heater.

10 The spacer 40 is a barrel of metal not solid in construction as this would potentially provide the heat exchanger 10 with an excessively high thermal inertia caused by heating of the volume of metal. The spacer 40 has a chamber 40a which is communicated or vented with the outside of the heat exchanger 10 through vent means in the form of a duct 41 allowing gas expansion to occur in a safe manner. If the spacer 40 cracks and leaks, cooking medium leakage may be observed or detected. Contamination may be particularly hazardous if water is used as cooking medium.

The heat exchange element 16 is conveniently designed to be removable from the housing 12 of the heat exchanger 10 which allows cleaning and replacement of the element 16 and housing 12, as necessary. Accordingly, the housing 12 may be provided with a flange 30 provided with bores 32 into which may be secured a plate or flange 34, connectable with the heat exchange element 16, by screws 37, keys or any like means. The flange 34 construction is not the only means of achieving this objective though it has the advantage of simplicity and ease of assembly/disassembly and conduct of replacement/cleaning operations.

In this respect, it is also desirable that the heat exchange element 16 be designed so that the electrical input and outputs 90, if heat exchanger 10 is electrical, are located at the flanged end of the heat exchange element or the same end 10a of the heat exchanger 10. This simplifies the assembly/disassembly of the heat exchanger by reducing the number of tasks

needed to be done by the operator. In this case, a double helical construction for the heat exchange element 16 is particularly advantageous, though a single coil could be used.

In the case where the heat exchanger 10 is electrical, the heat exchange
5 element 16 has an electrically conductive element 16a, typically a resistor wire 16b, running through the helix. This is surrounded by an insulation layer 16c of insulating material being a good electrical insulator and heat conductor such as magnesium oxide and, in the embodiment shown, a further outer shell 16d comprised of a nickel alloy inconel. This cross-sectional design is shown in
10 Figure 5. The material must not be reactive to any appreciable extent with cooking media.

While the heat exchange coil 16 may be of electrical, gas or other type, for example, the coil could carry a thermal fluid with the heat exchanger being designed accordingly, it is preferred at this time to employ an electrical
15 resistance type element 16 in which heat is generated by driving electrical current through a suitable length of material of resistance sufficient to provide the heat input required for the application.

The heat output of element 16 is a function of many parameters and cannot be set generally, it will be selected for the particular cooking application
20 taking into account the above factors, the nature of the cooking equipment, and additionally the volume of cooking medium and the temperature to which the cooking medium is to be heated. In a spray fryer of the kind developed by the Applicant, cooking medium this temperature will typically be in the range 180 to 210°C though the volume of cooking medium may vary between no more than a
25 few litres per minute to tens or even hundreds of litres per minute depending on the capacity sought for the particular cooking application.

The heat delivered by the heat exchange element 16 is controlled by a microprocessor control unit 100 programmed in accordance with the cooking application. The control unit 100 may include a graphical user interface as
30 described in PO 8943, "CONTROL UNIT", filed 2nd September, 1997, the contents of which are hereby incorporated by reference. In the context of a cooking operation, such as a spray frying operation, the heat exchange element

16 heat output may be controlled in accordance with the cooking medium temperature leaving the heat exchanger 10. This temperature is sensed by a suitable temperature probe, advantageously of NTC thermistor type. The heat exchanger 16 may also be controlled to maintain a particular heat output for a particular length of time, a particular food item or food item throughput or to provide a particular outlet temperature as a function of time. Other control programs are possible.

Cooking medium to be heated, or cooled, enters the housing 12 of the heat exchanger 10 through the inlet nozzle 20 which may be threaded or otherwise designed to allow connection with the delivery system to the heat exchanger 10. Flexible or quick couplings may desirably be adopted. In the case of a spray frying operation, the inlet nozzle 20 will typically be connected to piping communicating the heat exchanger 10 with an oil storage tank and cooking medium is delivered to the heat exchanger under the action of a pump of suitable capacity. Centrifugal pumps are preferred.

In the case of heating of cooking medium, it may be desirable to filter the cooking medium prior to entry of the cooking medium to the cooking medium chamber 14 of the heat exchanger 10 to prevent deposition and burning of fine food particles on the heat exchange element 16. This may also apply in other fields where the fluid to be heated may have fine solid particles present. Deposition of such scale is to be avoided.

As has been described hereinabove, the heat exchange element 16 is conveniently of electrical type and accordingly a source of electrical power is necessary. The power source may be AC or DC, rectification being employed if desired, and the heat exchange element 16 as well as other electrically driven components of an apparatus in which the heat exchanger 10 is employed is suitably and controllably connected through a solid state relay to the power source in a manner known in the electrical arts. The power leads should be suitably insulated to reduce electrical hazards.

The heat exchanger 10 may advantageously be operated in a pulsed manner with the control period arbitrarily selected to avoid loss of heating due to the frequency of the power source, where AC. The Applicant has found a 2

second control period to be suitable and the proportion of power delivered by the heat exchanger 10 is controlled in accordance with the fraction of the control period that the heat exchange element is "on" as shown in Figure 6. With this control period there is no adverse cooling effect due to power oscillation and power input may be calculated on the basis of RMS current and voltage values. Accordingly, there may be selected four output power levels other than zero heat output though the number and level is of no great importance, say 25% of full power, 50% of full power, 75% of full power and full power with interval being 0.5, 1.0, 1.5 and 2.0 seconds respectively. A continuous variation of power output level between 0 and 100% may be achieved. At one extreme the 0 to 100% interval is broken into 256 equal steps corresponding with digital 8 bit format allowing continuous adjustment. These timings may be varied in accordance with the nature of the cooking medium. That is, cooking media that are more heat sensitive; or which are more likely to be degraded due to the nature of the food items being cooked, e.g. fish, may be heated in a manner less deleterious to cooking medium quality.

The purpose of pulse width modulation control is to maintain power output and temperature at the heat exchange surface in contact with the cooking medium, that is the outside surface of the coils 16a, at a temperature below that at which the fluid will be subject to significant degradation by heat. Thus, the use of pulse width modulation may be very important to minimising heat degradation of cooking media.

Accordingly, in a case where multiple flow heaters are employed, the desired form of control will be such that the power output through each of the heat exchange elements is substantially the same. Thus, as the thermal characteristics of each heat exchanger have been selected accordingly each will provide equal power density at the surface of each heat exchanger element 16 of each heat exchanger 10. So, at 25% system power output the power density on the element 16 surface is only 25% of the maximum and the maximum would not typically be reached during cooking. This is gentler on the oil cooking medium. Therefore, the power density may be maintained at a level such that the temperature at the heat exchange surface is less than that at which

a significant degree of degradation of fluid occurs and at which a gentle but efficacious heating of the fluid is achieved. Indeed, power density may practically not reach 100% during the cooking except during the heating up period prior to commencement of cooking.

5 The heat exchanger 10 of the present invention need not be used in isolation, it may form part of a module of a plurality of heat exchangers used to heat or cool fluids in a particular process especially in commercial or industrial fryers. Three heat exchangers may desirably be utilised per module, each module being connected through solid state relays to a three phase AC supply
10 giving a balanced loading for each phase. The use of a module of this kind may allow more efficient control over the heat transfer process and such modules may be sold as separate components. For larger capacity commercial and industrial units, the multiple heat exchanger elements may be arranged and controlled in banks with the banks of elements being switched ON and OFF to
15 simulate proportional control as above described. For example, at 25% power input, a quarter (say) of the elements are switched on; at 50% power input half of the elements are switched on, and so on. Each element may be energised at its typically low maximum power output level.

Accordingly, where heat exchanger 10 forms part of a module, outlet
20 nozzle 80 may be suitably connected threadably or otherwise to the housing of a further heat exchanger. If desired, a pipe may be provided to simply deliver heated fluid from one heat exchanger to the next in sequence in a module. However, if there are more than two heat exchangers in a module, it is possible for heated cooking medium from one heat exchanger to be delivered
25 proportionally or wholly to any other heat exchanger in the module. The heat exchangers constituting the module may be connected in series or in parallel.

The heat exchanger 10 may be designed to include safety features. Therefore, for example, if sensed temperature of cooking medium leaving heat exchanger 16 is greater than a certain value or the rate of heating with time or
30 some such parameter is outside permissible limits-which may indicate a malfunction such as loss of pumping of fluid to the heat exchanger 16-it may be shut-down, advantageously in a manner that makes the equipment employing

the heat exchanger 16 safe.

In the above manner, the heat exchanger 16 of the present invention enables the achievement of a more uniform temperature distribution in the cooking medium and avoids, in the case of a heating operation, deterioration of oils, fats or other heat sensitive cooking media through substantial avoidance of local overheating. It is to be noted that a particular problem arises, in this respect, in the heating of cooking media, in sump or tank type heaters or boilers, such heating being as described, for example, in Critall British Patent No. 621821.

10 In the case when the heat exchanger 10 is a cooler, the heat exchange element 16 is designed to allow flow of a refrigerant fluid therethrough to absorb heat for fluid travelling through fluid chamber 14. The heat exchanger element 16 could be designed to have both heating and cooling capacity.

Referring now to Figure 3, heat exchanger 10 may be employed as the heat exchanger 22 in the spray cooking apparatus 100 of Patent Application No. WO 93/24040, the contents of which are hereby incorporated by reference. There a cooking medium, such as oil, is circulated through flow heater 22 for heating prior to spraying onto food items 36, through sprayers 60 located in the roof of cooking chamber 14, conveyed therethrough on conveyor 90. Sprayers may be located below the conveyor. Preferably, item 22 is a heater module containing a plurality of heat exchangers 10, which may each be heat exchangers 10 of the kind described herein. Such heat exchangers may be referred to as flow heaters.

Two such modules of three heat exchangers 16 each may advantageously be used, both having power of 10 kW, one provided for the top sprays and the other for the bottom sprays so that temperature may be adjusted independently. Very rarely, particularly cooking process may require different power modules.

Heat exchangers 10 may also be employed in other kinds of cooking apparatus such as vat fryers and multi-zone spray and vat fryers which may be employed in the cooking of various types of food items. The cooking apparatus may be employed for the frying of low fat dough products such as dough nuts as

described, for example, in Australian Provisional Patent Application No. PP0482 "DOUGH PRODUCT COOKER", filed 21st November, 1997, the contents of which are hereby incorporated by reference.

Modifications and variations may be made to the heat exchanger of the present invention by persons skilled in the art reading this disclosure. Such modifications and variations fall within the scope of the present invention.



THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A heat exchanger for heating a cooking medium comprising a housing; a cooking medium chamber in the housing for passage of cooking medium therethrough; and a heat exchange element formed as a coil to define a generally spiral path for the cooking medium to pass through the cooking medium chamber during the heat exchange process.
2. The heat exchanger of claim 1 wherein the heat exchange element is formed as a double helix electrical element, preferably energised in pulse wise manner.
3. The heat exchanger of claim 1 or 2 wherein the coil is arranged about a spacer defining, with the housing, the cooking medium chamber, the spacer having a chamber with vent means allowing accommodation for gas expansion within the chamber.
4. The heat exchanger of any one of claims 2 or 3 wherein the thermal inertia of the heat exchange element rectifies the frequency of pulses, the frequency being selected such that the heat exchanger element has substantially constant heat output as its surface for a given power input.
5. A cooking apparatus comprising a housing and a cooking zone, the cooking zone being supplied with cooking medium heated to desired cooking temperature by heat exchange means including at least one heat exchanger comprising a housing, a cooking medium chamber located in the housing for passage of cooking medium therethrough; and a heat exchange element formed as a coil to define a generally spiral path for the cooking medium to pass through the fluid chamber during the heat exchange process.
6. The cooking apparatus of claim 5 wherein said heat exchange means comprises a plurality of heat exchangers, preferably having equal maximum power output.

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7. The cooking apparatus of claim 5 or 6 wherein said cooking apparatus is a vat or spray fryer.
8. A method of heating a cooking medium for cooking of food items comprising introducing cooking medium to a chamber of a heat exchanger; and causing the cooking medium to flow in a generally spiral path formed by a heating element coil located within the chamber; and heating the cooking medium by the heating element coil to a desired temperature for cooking.
9. The method of claim 8 wherein the cooking medium is heated in the substantial absence of oxidising gases such as air.
10. The method of claim 8 or 9 wherein the heating element is energised in pulse wise manner at desired power level and frequency.
11. The method of claim 10 wherein pulse width is modulated by a control unit supervising operation of the heat exchanger.
12. The method of claim 11 wherein pulse width is controlled in accordance with the nature of the cooking medium or food items being cooked by the cooking medium.

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