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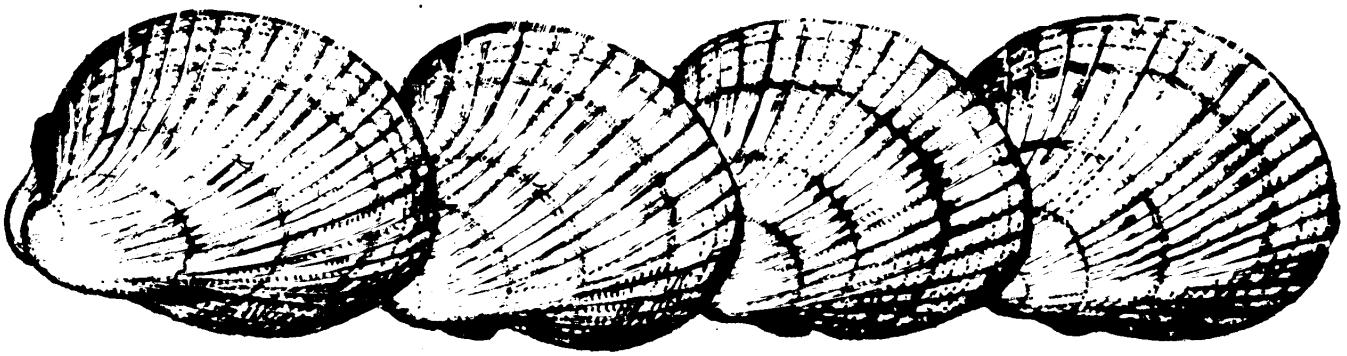
DIRECTORATE OF FISHERIES RESEARCH

HEAT PROCESSING OF COCKLES



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HEAT PROCESSING OF COCKLES

by P. A. Ayres

1. INTRODUCTION

The edible cockle (Cardium edule L.) occurs all round our coasts but is particularly abundant on the intertidal flats of large river estuaries where the major commercial fisheries are concentrated, e.g. the Wash and the Thames estuary. The cockle is a typical bivalve mollusc obtaining both food and oxygen by filtering the surrounding water. Water is drawn into the shell and expelled through a pair of tubes or siphons which are extended upwards into the water while the animal itself remains buried just beneath the surface of the sand. In some areas cockles may occur at densities as high as 500 per square metre and large quantities may be gathered by hand raking; at low densities, stocks may be fished commercially by using hydraulic suction dredges.

Typical estuarine habitats of the cockle are often subject to pollution by domestic sewage and there is a risk that pathogenic microorganisms (bacteria and viruses) may be accumulated by the animals during their filtering activity. In areas where levels of sewage pollution are such that there is a risk that disease may be transmitted to the consumer by eating raw shellfish, local authorities may make an order under the Public Health (Shellfish) Regulations 1934. These regulations allow a local authority to permit the sale for human consumption of shellfish from a prescribed area provided the shellfish have been treated by approved methods. In the Thames estuary cockles may be taken for human consumption provided they have been:

(i) subjected to a satisfactory process of cleansing at an establishment which is for the time being approved for the purpose by the Secretary of State for Health and Social Services; or

(ii) relaid in pure water for such period and in such places as may from time to time be approved for the purpose by the said Port Health Authority; or

(iii) subjected to a process of sterilisation by steam under pressure for at least six minutes in an apparatus which is for the time being approved by the said Port Health Authority; or

(iv) subjected to any other process of sterilisation which is for the time being approved by the said Port Health Authority.

Cockles are usually cooked before sale, and those taken from areas subject to an order usually conform to requirements (iii) or (iv) above. These methods have been employed in the Thames estuary over the last seventy years. In areas where no orders are in force the purpose of the cooking of cockles is to separate the cockle meats from the shells and to make them acceptable for

consumption. However, cockles from both clean and polluted areas may ultimately reach the same market and should conform to the same bacteriological criteria for human consumption.

This Laboratory Leaflet has been prepared primarily for cockle producers and for local authorities in areas where cockles are produced and/or processed. The aim is to provide an understanding of the different forms of treatments, their relative efficiencies and the criteria which may be employed to judge the treatment process and the final product.

2. OBJECTIVES OF HEAT PROCESSING

Cockles from some fisheries, e.g. Morecambe Bay, were traditionally sent to market in the raw state complete with shells. The high cost of transporting whole cockles of which at least 50% by weight is shell has meant that this procedure is now generally considered uneconomic except perhaps for small, local markets. Current practice favours the siting of processing plants at the nearest convenient landing place adjacent to the fishing area, thus considerably reducing the costs of handling and transportation. The degree of processing may vary between areas: it may be fairly rudimentary, using just sufficient heat to separate the cockle meats from the shells, usually applied as steam or hot water; it may be extended to ensure sterilisation; it may be followed by salting or bottling in vinegar prior to marketing.

Where cockles are taken from an area covered by an order under the Public Health (Shellfish) Regulations 1934, the minimum of heat treatment to meet public health needs is stated as treatment by steam under pressure for 6 minutes, although there is no precise definition of either the pressure to be applied or how the processing should be conducted. As with many other shellfish, prolonged heat treatment of cockle meats sufficient to sterilise them may result in very marked reductions in yield and lead to undesirable changes in the texture of the product which may become increasingly tough and 'rubbery' in texture. Clearly, therefore, the degree of heat treatment must be such as to produce a saleable product without undue reduction in yield, yet satisfy the public health requirement for a hygienically produced foodstuff, safe for the consumer.

Where no order exists the major objective of heat processing still remains a commercial one, i.e. the removal of cockle meats from the shells. This offers considerably more latitude in processing, and mention is made in section 3 of some of the methods employed.

3. METHODS OF TREATMENT

3.1 Traditional coppers

At the turn of the century cockles were often first laid in creeks adjacent to the boiling sheds to rid themselves of sand and mud and then boiled in cauldrons or large open coppers. Nets or bags of cockles were lowered into the coppers which contained water at, or approaching, boiling point. Immersion of the cold cockles lowered the temperature and the water had to be brought back to the boil. Bulstrode (1911) observed this process at first hand in various localities and noted that while those cockles in the bottom of the copper were in fact immersed in boiling water

those near the top were often lifted out of the water as a result of the opening of cockles beneath, and were 'steamed' rather than boiled. Although this process induced the cockle shells to open and the meats to fall out, it was insufficient to adequately cook those cockles near the top of the boiler. In some cases the boiled cockles were washed in water from nearby creeks prior to marketing. A combination of relaying cockles in sewage-polluted water, insufficient heat processing and possible recontamination by washing in polluted water inevitably gave rise to a number of cases of typhoid fever, which were frequently reported in the literature.

3.2 Introduction of steam pressure cookers

In the early 1900's the Thames estuary cockle fishery centred at Leigh-on-Sea employed some 200 people and produced three tons of cockles per week for the London (Billingsgate), Bristol and other markets. Cases of typhoid fever following the consumption of cockles laid in Leigh Creek and taken from polluted areas led cockle merchants to install simple sterilising equipment. Cockles were brought direct to the boiling sheds and placed in iron trays which were clamped into a simple iron box steriliser. A boiler produced steam which was conducted to the iron box at a pressure between 20 and 26 lb per square inch for a period of 5 minutes. After removal from the cooker the cockles were riddled and the meats passed through a series of tubs of tap water to remove shell, grit and detritus prior to packing in muslin bags and baskets for despatch to market. Sheds and boilers were inspected by officers of the Fishmongers' Company and samples were taken for bacteriological examination. Collection of cockles from any area in the Thames estuary was permitted, provided the process was approved by the Fishmongers' Company.

3.3 Retort cooking

Following concern about the bacteriological quality of the product, in 1950 the Port Health Authority and local authority conducted a number of experiments at Leigh-on-Sea to devise a cooking system which would both satisfy the Public Health Regulations and produce a commercially acceptable cockle. The tests showed that under-cooked cockles were very soft and jelly-like and did not stand up to being salted or handled without tearing. When cooking time was increased from 6 to 7 minutes cockles were not only tough but lost an additional 20% of their volume. The apparatus devised to satisfy both requirements consisted of a battery of three cooking pots each holding a bushel (8 gallons) of cockles divided between two wire mesh baskets. Steam from an oil-fired boiler was admitted under controlled pressure, but each pot or retort had a vent at the bottom to permit water from the cockles to drain away and to prevent any build up of steam pressure within the pot (Figure 1). After cooking the baskets of cockles were tipped into a riddle to separate the meats from the shells. This process, together with refilling the baskets with raw cockles, took approximately 2 minutes for each pot, i.e. a total of 6 minutes for the three cooking pots. As the pots were under steam for 6 minutes, the process was more or less continuous.

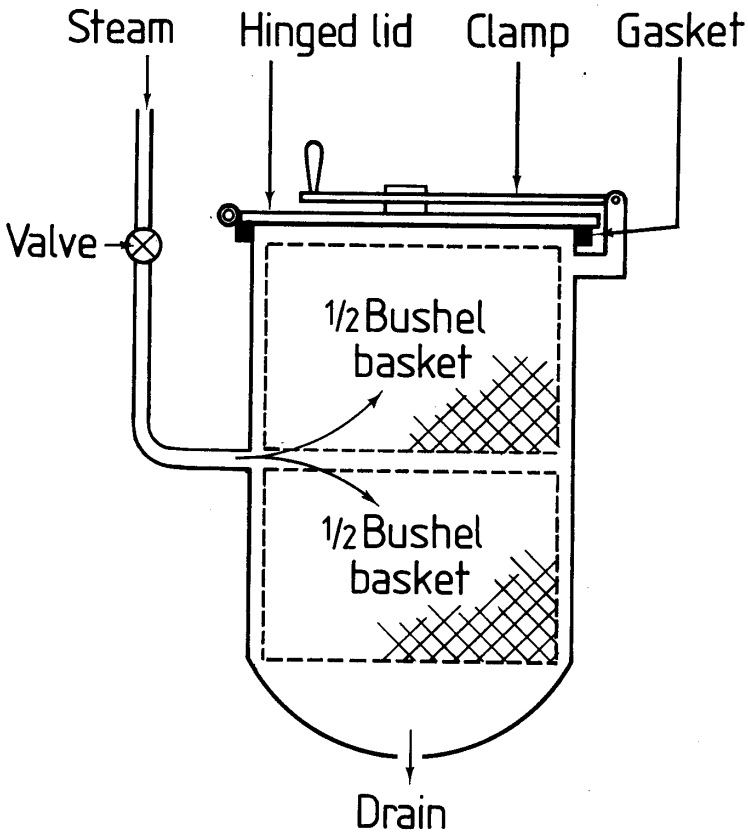

Figure 1 Pot or retort cooker

3.4 Introduction of mechanised fishing

In most areas, including the Wash and the Burry Inlet, local bye-laws of the Sea Fisheries Committees currently prohibit the use of mechanical fishing methods for cockles. In the Thames estuary, however, use of the continuous delivery hydraulic dredge (Pickett, 1973) has been accepted following its trial introduction in 1968, and it has been generally adopted at Leigh-on-Sea since 1971. Use of mechanical harvesting has made an important impact on a fishery whose methods had remained unchanged for many years previously. Dredging has permitted the exploitation of sub-littoral (submerged) cockle stocks and those littoral stocks whose density was too low to support a viable hand-raking fishery. In consequence, the amount of cockles landed is related mainly to the time engaged on fishing whereas other factors, such as the period of exposure, limit catches taken by hand-raking. On the debit, mechanical harvesting damages as much as 20% of the catch, cockles do not keep so well before cocking due to loss of water within the shells, and the increased number of shell fragments from broken cockles makes hand-picking of the cooked product difficult.

3.5 Continuous rotary cookers

Mechanisation of the fishing method inevitably led to the need for more mechanised cooking and handling techniques to cope with the increased output of

cockles. The rotary or 'Monobloc' cooker was introduced from Holland around 1970 as part of a new processing plant and this type of cooker was soon adopted at Leigh-on-Sea and elsewhere. Detailed arrangements of the rotary cookers vary considerably but are based on the principles illustrated in Figure 2. All employ a motorised rotating cylindrical steel chamber with a steam injection system along the central axis. The unit is slightly inclined and fitted with a shallow internal baffle forming a screw to carry cockles through the chamber continuously. Steam is supplied under pressure from an oil-fired boiler but since the chamber itself is not under pressure there is a temperature gradient along the length of the cylinder (range from 85^{o} to 96^{o}C). In current designs of the 'Monobloc' system, it is normally impossible to increase the retention or 'cooking' time beyond 3 minutes and in practice the contact time is usually only 90 seconds or less.

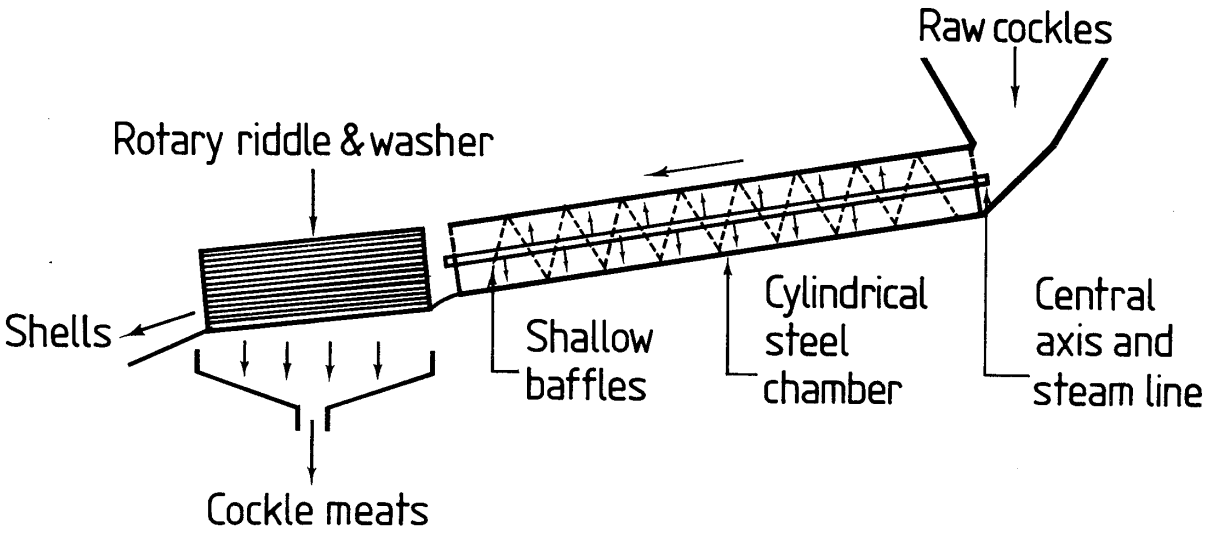

Figure 2 Continuous rotary cooker 'Monobloc' system

While existing 'Monobloc' rotary cookers are very effective for separating meats from shells (sometimes called shucking) the temperatures and contact times are insufficient to allow enough heat to penetrate the cockle meats to adequately cook or sterilise them. In winter conditions, when the shell liquor of raw cockles may be at temperatures near to freezing or may even be frozen, such short-term heating may be sufficient only to thaw the cockles and to separate meats from shells. Therefore, in any area where there is an Order under the Public Health (Shellfish) Regulations 1934, the current models of the continuous rotary cooker are not able to provide heat sterilisation to a level expected of an approved method.

3.6 Modified 'Leigh' method

In Leigh-on-Sea reappraisal of processing methods, following the marketing of insufficiently cooked cockles in 1976, led to development of a new system designed

to meet the following objectives: (1) to apply heat rapidly and effectively so as to reduce bacterial levels without adversely affecting the yield and texture of the product; (2) to reduce opportunities for recontamination during subsequent handling and processing.

Experiments in the laboratory and at Leigh-on-Sea suggested that a significant reduction in the bacterial content of cockles occurred during the first few minutes of immersion in boiling water; this was followed by a more gradual decline in bacterial numbers as boiling time increased. As mentioned earlier, there is, however, a point where the texture and yield of the cockle are adversely affected and this point seemed to occur after 4 minutes boiling. It was also shown that sterilisation was most effective if only the meats rather than whole cockles (i.e. plus shell) were exposed to heat and that immersion in boiling water was more effective than exposure to steam. Thus, treatment of meats alone avoided loss of heat to the shells and reduced recontamination which took place during riddling, washing and grit removal after cooking. The following procedure was therefore devised:

(a) wash raw cockles externally;

(b) separate shells from meats by subjecting whole cockles to $1\frac{1}{2}$ minutes (maximum) heating by steam or boiling water;

(c) riddle;

(d) wash, sort and rinse meats in tap water to remove shell fragments and sand;

(e) boil meats for only 4 minutes in a boiling water bath (achieved by conducting live steam through a heating coil);

(f) remove meats from water bath and cool by spraying with continuous supply of cold mains water - not recycled, previously-used cooling water;

(g) brine or pack as required.

This method was first tried in a single industrial plant, and has since been adopted by commercial producers at Leigh-on-Sea. The product is commercially acceptable, and meats are of a satisfactory quality.

3.7 Other continuous methods

In areas where no Public Health Orders are in operation the method of processing depends on local circumstances, and several systems are used. Usually these systems are designed to speed up the processing time and therefore they work on a continuous throughput. Consequently, separation of meats from shells is the primary objective, and sterilisation of the meats is very much a secondary consideration. Three of the systems in use in different parts of the country are shown in Figure 3.

Methods A and B in Figure 3 utilise boiling water to provide the heat source; differences in design give varying retention periods of the cockle within the apparatus. In method A the cockles are treated in a rotary screen on the principle of the 'Monobloc' cooker but the screen, which is of larger diameter and partially immersed in boiling water, gives a retention time of 3-4 minutes. In method B

the cockles are carried through a boiling water bath on a flexible belt, the speed of which can be adjusted to give retention times of up to 4 minutes. One disadvantage of this second system is that the water is virtually static and raw cockles introduced at one end may lower the water temperature below boiling point in the first few feet of the length of the trough and thus the boiling time is less than the immersion or retention time.

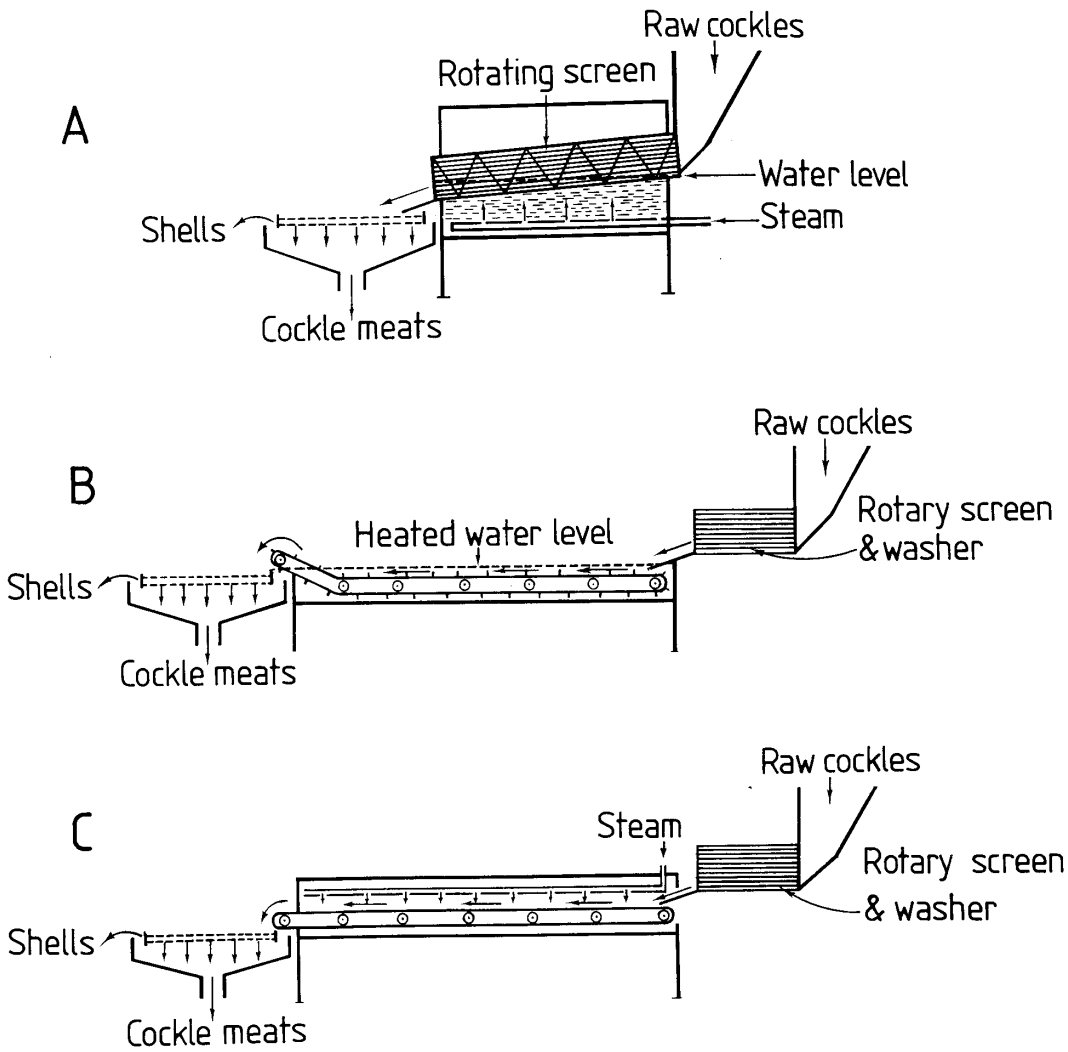

Figure 3 Continuous cooking methods

Method C carries cockles on a continuous flexible belt through an enclosed steam chamber. Steam is injected under pressure along the whole of the longitudinal axis of the chamber directly onto the cockles. Although the belt speed can be adjusted, in current models maximum retention time in the steamer is limited to under 3 minutes because at slower speeds cockles from the rotary screen obstruct the belt. Modifications of design would probably overcome much of this and permit a greater retention period.

To summarise, therefore, most of the continuous cooking methods in use provide insufficient heat treatment to meet public health needs. Unfortunately, because of their design, these plants will require major design modifications to yield a product comparable with that produced by the modified 'Leigh' method (see section 3.6).

4. DESIGN AND OPERATION OF PREMISES

4.1 General notes

Whatever type of processing method is employed for cockles, it should be borne in mind that the final product is a foodstuff and should be produced in a hygienic manner so as to reduce all possible risks to the consumer. As noted earlier, a wholly sterile product cannot be produced since this would be incompatible with an economic yield or with acceptable texture and flavour. As the product contains bacteria after heat treatment, it is particularly important that special attention should be given to hygiene during subsequent processing, as it is liable to recontamination during the sorting and washing stage and is often sold without further processing.

In no commercially acceptable cooking process is it possible to achieve total sterility, but compared with the number of bacteria originally present (as measured by the total plate count) reductions in excess of 95% can be achieved. This in itself poses special problems because the freshly cooked, warm cockle tissue provides an ideal substrate for multiplication both of the remaining bacteria and of any organisms introduced to it by, for instance, handling or cross contamination between raw and cooked cockles. A good example of such a bacterium is Staphylococcus aureus which may occur on the skin and in the nose and throat of healthy humans, as well as in wounds, sores and boils. Some forms of this organism produce potent toxins in foods which, if ingested, can give rise to severe and distressing food poisoning. Reduction of the normal bacterial flora of the cockle during processing, and the warm state of the cooked meat and the washing waters may provide an opportunity for pathogenic bacteria such as Staphlococci to multiply. Other factors which contribute to microbial contamination of the cooked product include:

(i) contamination by hands or utensils as staff move from one task to another, such as from handling raw cockles to handling processed ones;

(ii) failure to quickly cool the warm cockle meats after final cooking, so permitting bacterial growth to undesirable levels;

(iii) unhygienic handling and storage of the product or delays in further processing;

(iv) packaging and transport in a manner which will permit contamination or bacterial growth, e.g. at too high a temperature.

A suggested layout for cockle processing premises is shown in Figure 4. Adoption of the principles illustrated and attention to the points which follow (section 4.2) would make a substantial contribution towards the production of a safe and wholesome product.

It cannot be over-emphasised that, however clean and efficient the premises and facilities are, the ultimate success or failure in producing satisfactorily processed cockles rests with the personnel who operate the plant. To this end the points relating to personnel should receive special attention and all staff should be reminded that they have a personal responsibility as well as a shared one. All workers concerned with any stage of the processing must pay very close attention to personal hygiene.

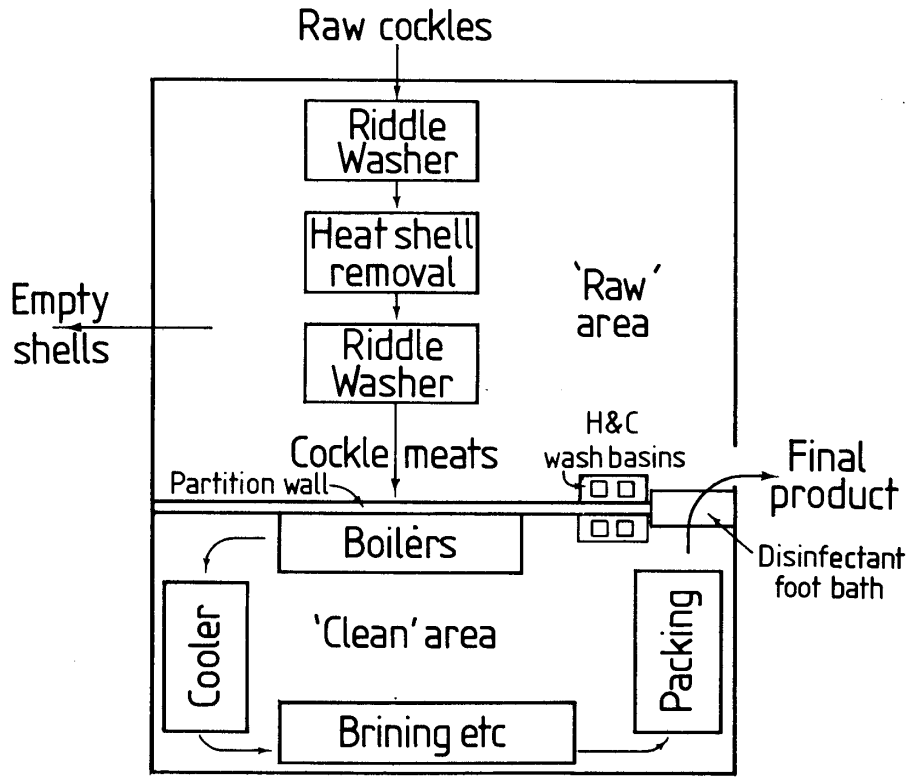

Figure 4 Suggested general layout for cockle processing premises.

4.2 Guidelines for the hygienic production of cooked cockle meats

4.2.1 Raw material

(a) Every attempt should be made to exploit cockle stocks from unpolluted areas rather than areas known to be polluted.

(b) Raw cockles should be protected from extremes to temperature (e.g. frost or hot sunshine) and from fouling or contamination by domestic animals, fuel oil, etc.

(c) Soon after catching raw cockles should be washed with clean sea water or tap water to remove excess mud and sand; they should not be washed or 'freshened' by immersion or rinsing in polluted sea water found in docks, creeks etc.

(d) Cockles should be processed as soon as possible after being fished and not left longer than overnight, i.e. not more than 18 hours.

4.2.2 Premises

(a) Toilet and hand washing facilities with hot and cold water and disposable towels should be provided on-site and be accessible to all staff.

(b) An adequate supply of cold, mains water should be available.

(c) Working surfaces, equipment and containers should be of an impervious

material which is easily cleaned and maintained e.g. stainless steel, plastic.

(d) Premises should be well lit, with smooth drainable floors, salt-resistant concrete finishes, and with a clean and uncluttered interior.

(e) No domestic animals should be allowed to enter the premises.

4.2.3 Processing equipment

(a) All equipment, particularly that which comes into contact with the cooked product, should be of stainless steel or other non-porous material for easy cleaning.

(b) At the beginning and end of each day's processing all equipment should be thoroughly washed and scrubbed down, preferably with a sanitizer designed for food processing premises (Tatterson and Windsor, 1970).

(c) All equipment of a mechanical nature should be regularly serviced and kept in good working order.

(d) Accurate pressure and temperature gauges should be installed together with a reliable timing device for monitoring the processing procedure.

4.2.4 Personnel

(a) Staff working on the 'clean' side of the processing establishment should be provided with suitable protective clothing, e.g. white coats, gloves and head covering, should be worn at all times.

(b) There should be no interchange of staff between 'clean' and unclean areas while processing is being carried out. If a move from the raw to the cooked area is absolutely necessary, boots, hands and arms should be washed thoroughly and the outer clothes should be changed.

(c) Any member of staff who has any cuts, sores or abrasions should have the affected area suitably dressed and covered. Where possible such persons should undertake only those duties which do not involve their contact with cooked cockles.

(d) Staff should be encouraged to notify the management of any illness, particularly sickness and diarrhoea, and should be permitted time off until they recover.

(e) Smoking and the entry of unauthorised personnel to processing areas should be prohibited.

(f) At all times the process should be supervised by one person who understands the principles involved and is able to ensure the correct operation of equipment.

4.2.5 Final product

(a) Cooked cockles should be cooled rapidly and hygienically by cold water spray or by direct immersion in cold running tap water in which the bath temperature does not exceed 15°C.

(b) After processing fresh cockles should be stored in brine, dry salt or acetic acid or be deep frozen by any acceptable technique.

(c) Concise records of each batch, including date produced, date marketed and source, should be kept. Such information plus the producer's name should appear in full or coded form on the label of each package before marketing.

(d) Cooked cockles should be placed in clean muslin bags or in an equivalent, and allowed to drain into a regularly cleaned impervious tray. Unperforated polythene bags retain liquors from the meats and are not recommended.

(e) During transportation and marketing, bags of cockles should be placed within another container or containers from which the liquor can drain, to prevent contamination and contact with unclean surfaces.

(f) When possible, transportation to market should be rapid and take place only under cool conditions.

5. MICROBIOLOGICAL SAMPLING

Historically there is a strong link between the consumption of raw molluscan bivalve shellfish (oysters, cockles, and mussels) and the transmission of enteric diseases such as typhoid, cholera and dysentry. Improvements in standards of sewage treatment and disposal, and in personal and food hygiene, have, in the United Kingdom at least, made such occurrences very much a thing of the past. However, outbreaks still occur in parts of Europe and serve to demonstrate that the risk, however small, is still present. In recent years the possibility of transmission of viral diseases such as infectious hepatitis and viral gastroenteritis have been clearly demonstrated and emphasise the need for continued vigilance.

Processed cockles, like all foodstuffs, need to be examined periodically to ensure they are of a satisfactory bacteriological quality. Bacteriological examination is carried out for two reasons. Firstly, it can indicate whether the cooking process is adequate for the destruction of sewage organisms taken up by the cockles from the water in which they live. Secondly, the numbers of other bacteria present demonstrate whether or not recontamination and regrowth of bacteria due to inadequate attention to hygiene has taken place.

It is normal practice for health authorities to take samples at the processing plants in order to carry out these bacteriological tests. Intensive sampling is often carried out when a new process is first put into operation, but thereafter regular or routine testing of the final product is generally all that is necessary to ensure that the process is satisfactory.

For routine purposes it is usual to examine shellfish for the present of coliform bacteria, particularly Escherichia coli (E. coli). These bacteria are common inhabitants of the human gut and their presence in shellfish is an indication of pollution by sewage. E. coli are more numerous in sewage than are pathogens such as Salmonella and are easily identified by simple and rapid techniques. In addition their survival in water and in shellfish is similar to that for most pathogens and the number present gives an indication of the risk of pathogenic bacteria also being present. The numbers of E. coli and coliforms can therefore be used as a basis for judging the quality of raw cockles (of how polluted they are) and of the cooked product (of whether cooking and hygiene are adequate).

To determine that bacterial reduction during heat processing is adequate and that subsequent handling is hygienic, routine examination of cockle meats should include estimates of the free-living bacteria which grow at 20°C and 37°C. This can most readily be done by means of the total plate count.

Some typical results of bacteriological examination of raw cockles and of cockles processed by the retort and 'Monobloc' systems showed that these processes were generally effective when judged by the reduction in the numbers of E. coli and coliform bacteria (Table 1). The immersion of cockles in boiling water

Table 1 Effect of heat treatment on the numbers of coliforms/E. coli in cockles

Method of heat treatment	Test	Steaming time (minutes)	Number (g)			
			Raw		Cooked	
			Coliforms	E. Coli	Coliforms	E. Coli
Retort	1	4	235.6	52.4)		
	2	4	>400	64.0)		
	3	4	275.6	55.2)	Absent from 2.5 g tissue	Absent from 2.5 g tissue
'Monobloc'	1	1½	3.6	< 0.4)		
	2	1½	11.6	7.2)		
	3	1½	0.8	0.4)		
	4	1	<500	36.8	<500	10

for various periods of time showed that as little as 1 minute was sufficient to achieve removal of E. coli and coliforms, but total plate counts on the same samples showed that the product was not 'sterilized' or bacteria-free even after 6 minutes boiling (Table 2). It is apparent that heating has the most effect on bacteria growing at 20°C; these are largely part of the natural marine bacterial flora of the raw cockle and therefore sensitive to heat. Bacteria growing at 37°C, a group which includes potential pathogens, did not show such a large reduction, mainly because these species are less sensitive to the heat of sterilisation.

Table 2 Effect of boiling time on the bacterial content of cockles

Sample	Coliforms (g)	E. coli (g)	Total plate count (g)					
			20°C	Reduction of numbers (%)	30°C	Reduction of numbers (%)	37°C	Reduction of numbers (%)
Raw cockles	184.8	71.2	7.56×10^5	-	2.05×10^5	-	1.5×10^4	-
Boiled (minutes)								
1	)		1×10^3	99.87	1.19×10^4	94.2	1.1×10^4	26.7
2	)		9.7×10^2	99.88	7.9×10^3	96.15	1.04×10^4	30.7
3	) Absent from	Absent from	7.6×10^2	99.90	8.3×10^3	99.95	9.9×10^3	34.0
4	) 2.5 g tissue	2.5 g tissue	6.2×10^2	99.92	7.5×10^3	96.34	9.3×10^3	38.0
5	)		5.9×10^2	99.92	9.6×10^3	95.32	8.4×10^3	44.0
6	)		2.9×10^2	99.96	7.2×10^3	96.49	6.0×10^3	60.0

After cooking, additional bacteria are introduced into the product during handling; although this is unavoidable, it is important to prevent the introduction of specifice pathogens and of large numbers of bacteria which may cause spoilage and minor types of food poisioning. Table 3 demonstrates bacteriological changes that take place when using 'Monobloc' or retort methods as an early stage in the processing:

following cooking there is usually an increase in bacteria as a result of handling and washing. In contrast, results of the modified 'Leigh' method, as shown in Table 4, compare favourably with those obtained in laboratory experiments.

Table 3 Bacteriological results of cockles sampled at various stages during processing

Cooking method	Cockle sample	Coliforms (g)	E. coli (g)	Total plate count (g)			Water temperature at each stage (°C)
				20°C	30°C	37°C	
'Monobloc'	Raw	3.6	<0.4	6.7×10^4	3.2×10^5	5.2×10^3	
	Cooked	< 0.4	<0.4	3.2×10^3	2.5×10^3	2.2×10^3	6.0
	Cooled	131.6	4.0	2.0×10^5	2.3×10^5	1.6×10^5	18.5
	Brine bath	122.0	<0.4	2.0×10^5	2.2×10^5	2.3×10^5	9.5
	First wash	17.6	<0.4	1.5×10^4	2.1×10^4	2.0×10^4	8.0
	Final product	8.4	<0.4	8.2×10^2	8.7×10^3	1.2×10^4	6.0
Retort	Raw	1.6	<0.4	1.9×10^4	7.0×10^3	1.2×10^4	
	Cooked	< 0.4	<0.4	2.5×10^3	4.8×10^3	4.5×10^3	6.0
	Cooled	>500	<0.4	1.2×10^6	1.3×10^6	6.1×10^5	22.0
	Brine bath	8.4	<0.4	1.3×10^5	2.6×10^5	2.0×10^5	22.0
	First wash	0.4	<0.4	4.5×10^4	4.2×10^4	4.7×10^4	10.0
	Final product	2.4	<0.4	6.5×10^4	4.5×10^4	4.3×10^4	9.0

Table 4 Bacteriological results from cockle processing plants using the modified 'Leigh' method

Producer	Nature of sample	Coliforms (g)	E. coli (g)	Total plate counts (g)					
				20°C	Reduction of numbers (%)	30°C	Reduction of numbers (%)	37°C	Reduction of numbers (%)
A	Raw cockles	440.8	140.8	3.2×10^4	-	3.1×10^4	-	2.3×10^4	-
	Cooked cockles after cooling	< 0.4	< 0.4	4.7×10^3	85.4	1.5×10^3	95.2	8×10^2	96.6
B	Raw cockles	330	76.4	2.6×10^4	-	1.9×10^4	-	2.3×10^4	-
	Cooked cockles	< 0.4	< 0.4	1×10^3	96.2	8.3×10^2	95.7	2×10^3	91.2
	Cooked cockles after cooling	< 0.4	< 0.4	3.5×10^3	86.6	5×10^2	97.4	2×10^3	91.2

Little is known about the behaviour of viruses in foods subjected to heat processing, but it is likely that a process which results in substantial reduction of bacterial numbers will be similarly effective with viruses. It is prudent, therefore, to attempt to reduce total plate counts to the lowest level compatible with a product of saleable texture and quality and to maintain this throughout any subsequent handling.

Consideration of product standards based upon absolute numbers of bacteria would be misleading since numbers of bacteria in themselves are not always of relevance and the total plate count of raw cockles may vary throughout the year. In practice a reduction of 90% of the bacteria present in the raw product is possible during processing (see Table 4). However, in some circumstances a greater reduction may be necessary, e.g. where the cockles come from a grossly polluted source, or where they are likely to be stored raw before they are marketed. Some cockles are bottled before sale and such packs are normally pasteurised, so in effect they receive two separate heat treatments. Others are commonly marketed in a salted or brined form or in a solution of acetic acid. The results of bacteriological examination of these products at the market level show that the use of acetic acid effectively reduces total plate counts to a very low level but that total plate counts of salted or brined cockles often approach levels similar to those of the raw product. This finding

stresses the importance of good hygiene at all times during the processing and handling stages of production.

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