Reviews.

Essay-Review.

The Production of Clean Shellfish.

By J. H. Orton.

The Report on Mussel Purification[1]) by Dr. R. W. Dodgson is the outcome of extensive researches made at the direction of the Ministry of Agriculture and Fisheries, England, with the object of evolving a practical and economic method of placing living mussels (*Mytilus edulis*) on the market as a sound food-product. The report describes the means by which that end was attained, and also gives a survey of the fundamental problems bearing on the sewage pollution of shellfish from the point of view of Public Health.

It was known that mussels may be unsuitable as food from at least two entirely different causes, namely (1) a vaguely defined toxicity due to the physiological condition of the mollusc itself and (2) the possibility of the bivalve carrying and passing on to the consumer harmful bacteria, whilst remaining otherwise healthy and sound. The author's medical training and experience enabled him to attack these problems at an advantage, while the report abounds in instances of his patience and ability to meet and assess the value of the practical difficulties which were encountered in devising an economic scheme of purification.

Dr. Dodgson's researches into the recondite literature of diseases due to eating mussels are summarised as follows:—

"1) 'Mussel poisoning', as generally understood, connotes any indisposition following the consumption of mussels; with the exception of the most important, namely, those due to specific (e. g., bacterial) infections, such as typhoid fever.
2) The widely held popular view that all manifestations of poisoning, due to the consumption of mussels, arise from a common cause, inherent in mussels, is erroneous.
3) 'Mussel poisoning' includes at least three pathological conditions, or types of conditions, namely:—

[1]) Report on Mussel Purification. Min. of Ag. and Fish. Fishery Invest. Series II, Vol. X, No. 1, 1928. London, 1928.

a) 'Musseling', or the erythematous form, which is due to properties inherent in the mussels. It affects a limited number of specially susceptible people, who should avoid eating mussels. The symptoms are of short duration, and unpleasant whilst they last; but are never of serious import.
b) The paralytic form, always grave and even fatal. Its cause is not definitely known, but it is always due to mussels from foul or stagnant waters. It is extremely rare (some 8 to 10 cases only being on record). The danger of contracting it may be reduced to such small proportions as to be probably entirely negligible, if elementary precaution be exercised; and especially if only purified mussels be eaten.
c) The bacterial food-poisoning form. If purified mussels only be eaten, the risk is probably not greater than that attaching to the consumption of other meat or milk foods, or even food in general.

4) Mussels, in common with other shellfish, and fish in general, contain a certain amount of arsenic, and may contain copper; but evidence that illness may be caused by these substances is lacking.
5) Certain popular conceptions, that poisonous properties reside in the 'beard', foot, or other parts of the mussel, are erroneous."

Thus the author shows that most of the diseases arising solely from the physiological constitution or condition of mussels may be avoided by the consumption only of the purified bivalve, whose origin can be vouched for. Some human individuals have a constitution to which mussels are inimical, and should therefore never eat mussels; while none should eat mussels from stagnant waters, such as occur frequently in docks. The mode of death — when death occurs — from eating mussels from these latter situations is by asphyxia, and it is at least a striking correlation that the respiratory centre in man (and other warm-blooded animals) should be affected by some substance produced in mussels that have been living in a situation where lack of oxygen is probably of common occurrence. As Dr. DODGSON has shown that mussels can live as long as 24 days under anaerobic conditions, it would seem that in the lack of oxygen this mollusc produces in its tissues (liver ?, DODGSON) some substance (Mytilotoxine, BRIEGER), which possibly controls but is certainly connected with the metabolism of the tissues under anaerobic conditions. It would appear that this substance retains and imposes an analogous influence on the tissues when transferred to man, with, however, lethal effect. Further researches on this problem offer a promising field to the human physiologist.

After disposing of the relatively minor troubles due to eating mussels, the author attacks the main source, namely, diseases due to specific infections, e. g. typhoid and related fevers, incurred by eating the uncooked flesh.

The evidence for the transmission of these diseases by bivalves in general and by the mussel and the oyster in particular is given and critically examined. The conclusion is arrived at that although absolute proof — such as might be obtainable from *ad hoc* feeding experiments on man —

of transmission is not available, yet "the evidence in question is such as to establish the causal relationship between the consumption of polluted shellfish and typhoid fever, beyond reasonable cavil or doubt". In this view the author is supported by many distinguished Medical Officers of Health (see also Journ. Roy. San. Institute, Nov. 1928, p. 283).

Thus the problem of producing a sound food-product in living mussels was reduced to that of freeing otherwise healthy molluscs from any typhoid or related bacteria; or other harmful material, which they may have taken into themselves from waters polluted by sewage or other noxious substances.

Academic researches had shown that the mussel and other economic bivalves feed in a simple manner on the organic material suspended in the surrounding water. This method is essentially as follows:— The shell space around the body of the bivalve is divided into two chambers between which the gill or beard is suspended as a partition. The gill is perforated by slits or holes and is furnished with various sets of microscopic whips or cilia. Certain sets of cilia beat rhythmically in one direction to maintain a large flow of water through first one chamber, then through the slits in the gill into the second chamber and finally out of the shell. Other sets of cilia on the gill arrest all or most of the particles in the water-stream and thus the gill acts as a very fine sieve. The collected food-particles are conveyed by other sets of cilia on the gill towards the mouth. If the collected food material is apparently suitable as food it is eaten, if it is not suitable, it is usually rejected by a special mechanism. It follows from the mode of feeding, that bivalves take into the shell-spaces from the surrounding water all kinds of finely-suspended material.

In order to obtain bivalves free from bacteria, it was therefore necessary to devise a method of treatment which would result not only in the removal of the entire gut-contents, but would also wash the shell-spaces, and in addition the outside of the shell, free from bacteria. By a series of experiments the author proved that a functioning mussel will evacuate ingested gut-contents in one and a half hours if the ingestion of food-material be continuous, and that under the conditions eventually established for purification the gut-contents are always evacuated (macroscopic observations) in one night's treatment in a sample cleansing tank. Extensive bacteriological analyses of mussels purified in test-cleansing tanks also proved that virtual if not actual purity was attainable, and a practicable economic scheme was devised.

This scheme has been applied on a commercial scale at Conway for a period of twelve years; it has been tested and improved, and under competent supervision may now be regarded as an established practical economic method of placing living mussels on the market as a sound food-product.

The principle of the method of purification is simple: freshly collected bivalves, which have, however, been out of water for some hours, are immersed overnight in a large volume of freshly »sterilised« sea-water. In two such successive immersions — with an intermediate tank-cleaning process — mussels *purify themselves* to the highest standard of purity. (It has been found, however, that oysters require three such immersions to attain a similar degree of purity.)

Fig. 1. General view of mussel purification installation and experimental tanks at Conway.

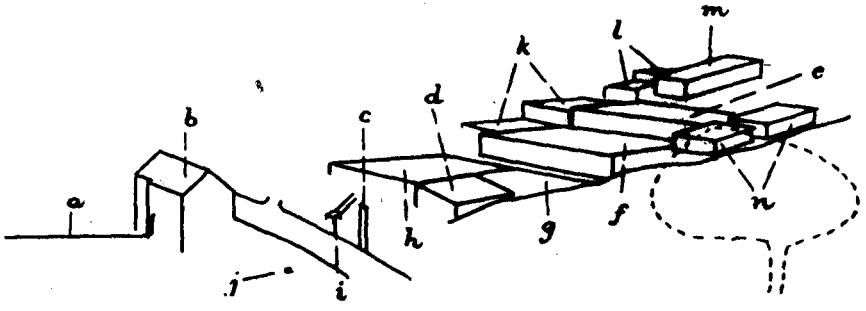

Fig. 2. Explanatory diagram of Fig. 1.

a Intake main. *b* Engine house and office. *c* Lift. *d* Mussel shed. *e* STORAGE TANK. *f* CHLORINATING TANK. *g* and *h* CLEANSING TANKS. *i* Chute for loading carts. *j* Drain exit from tanks. *k* and *l* Open tanks for oyster experiments. *m* Covered tanks for oyster experiments. *n* Sheds for oyster tiles.

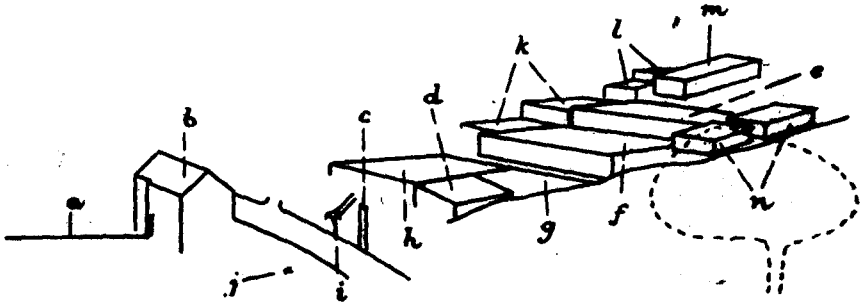

Fig. 2. Explanatory diagram of Fig. 1.

a Intake main. *b* Engine house and office. *c* Lift. *d* Mussel shed. *e* STORAGE TANK. *f* CHLORINATING TANK. *g* and *h* CLEANSING TANKS. *i* Chute for loading carts. *j* Drain exit from tanks. *k* and *l* Open tanks for oyster experiments. *m* Covered tanks for oyster experiments. *n* Sheds for oyster tiles.

A brief description of the commercial method is as follows. The plant in use for the scheme at Conway is shown in Fig. 1, and in skeleton form in Fig. 2. For mussel purification three large tanks (*e*, *f*, and *g* or *h*, in Fig. 2) are used in series. Tank *e* is a store tank and receives untreated sea-water; Tank *f* is used only for the operation of sterilising the sea-water; Tank *g*, or alternatively Tank *h*, serves as the cleansing or purifying tank. The shellfish which are to be purified are first well washed by a high pressure jet of water from a hose, then placed in the empty cleansing tank *g* on wooden grids. In the meantime the untreated water in tank *e* is run into tank *f* and at the same time mixed with a solution of bleaching powder in such quantity as will give an estimated potential concentration of 3 parts in a million of available chlorine when the tank is full. The amount of chlorine added is sufficient (in this locality) to sterilise the water (as regards non-sporing bacteria) and leave an excess. Therefore, when tank *f* is prepared it contains sterilised sea-water with a certain amount of chlorine in a state which might be harmful if it were added to the shellfish. The excess of harmful chlorine is, however, got rid of by treating the water from tank *f* with sodium thiosulphate as it is run into tank *g*. Thus tank *g*, after receiving the shellfish to be cleaned, is filled up with sterilised and innocuous water. In this water the shellfish, that is mussels or oysters, or other kinds, open freely and gradually clear their alimentary canal and shell-spaces of harmful bacteria and other products. To facilitate the removal of faeces and other rejected products, the grids containing the shellfish are raised from the bottom of the tank, so that when the tank is emptied the products rejected by the bivalves can be cleared from the bottom of the tank before the next dose of sterilised water is added. In this way mussels contaminated to the extent of 500 to 600 sewage bacteria per c.c. of minced mussel and shell-liquor can be purified constantly to a standard of only 1 to 4 residual, but not necessarily sewage, bacteria per c.c. Similar results have been obtained with oysters after 3 days' treatment, and so far as is known, in both cases, without any loss of commercial value. The tanks used are very large; *e* and *f* each having a capacity of 80,000 gallons, and *g* a capacity of 40,000 gallons. These tanks have enabled about 20,000 quarts or 16 tons of mussels to be cleansed per week at a cost to the fishermen of ls. per bag of 140 lbs.

Before being packed in sterilised bags for transport to the market, the mussels are treated for not more than one hour in a bath containing three parts of available chlorine in order to sterilise the outside of the shell. From the time the mussels are collected on the foreshore to their dispatch in bags after purification not more than four days are normally required.

The whole process of purification has been worked out in detail meticulously, and regulations are given for directing and safeguarding every stage of the operation. The author is insistent upon the fact that the bivalves purify themselves in clean water, and herein lies the simplicity and the brilliancy of the scheme. The earlier methods of purifying bivalves by the use of free chlorine relied on the direct action of this reagent upon the water in which the bivalves themselves were immersed; in DODGSON's method free chlorine is never in contact with the bivalves during the essential and internal purifying process. FABRE-DOMERGUE evolved a scheme

for the self-purification of oysters in filtered running water, and JOHNSTONE and SCOTT later tried a similar scheme for mussels, but no one has used the author's combination of sterile water with subsequent self-purification. The earlier workers on the subject will readily perceive the advantages of the new method, and it is interesting to note that a train of research workers back to JOHNSTONE, FABRE-DOMERGUE, KLEIN, HERDMAN and BOYCE have contributed to its fruition.

The final solution of the problem was not attained, however, without a large amount of original detailed investigation by the author into the

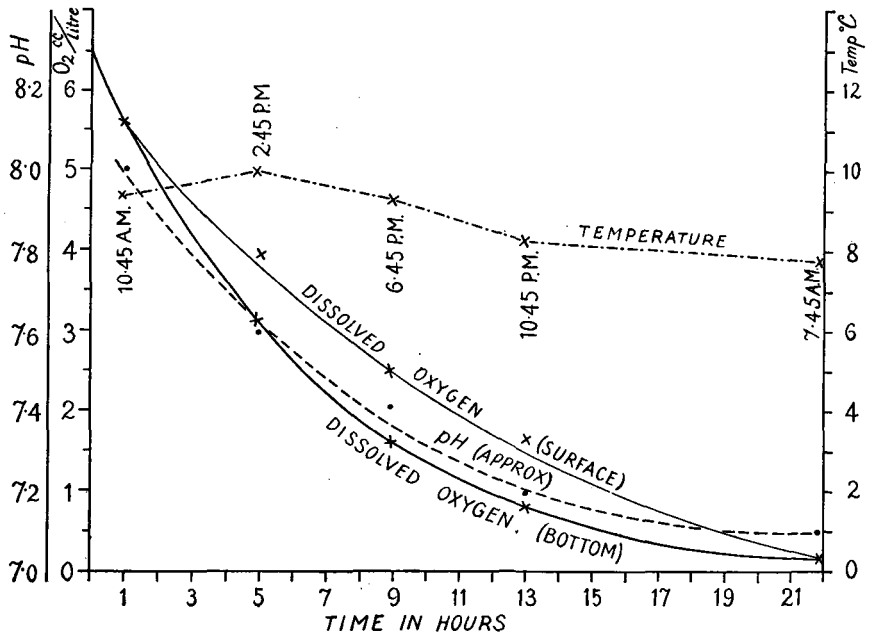

Fig. 3. Variation in oxygen content, *pH* and temperature in a mussel cleaning tank during a second day of treatment.

biology and physiology of the mussel, into bacteriological methods and, indeed, engineering problems. To the biologist the section of the report on "The physiology of the mussel with special reference to purification" (pp. 154—222) is a revelation in the study of habits. One astonishing result given in this section is reproduced in Fig. 3 above. The graphs given in this figure show the reduction in the oxygen content at the surface and the bottom of the water (ca. 1 metre deep) covering a batch of mussels in the purifying tank during the second day of treatment, in October. The amazing fact emerges that in a large tank with a large surface of water exposed to the air, practically all the oxygen is used up by the active mussels within about 21 hours. It seems probable that this single observation may be exploited to give far-reaching results in hydrobiology. Similar delightful pieces of work are recorded in this section; for example,

mussels are shown to be sensitive to light, and "can only be relied upon to open and function (i. e. produce water currents and feed) in the dark, or in very subdued daylight. Hence in the cleansing operations it is stipulated that "the mussels must have 'one night' in the tanks during each phase of the process". Mussels may function at any temperature between 0° and 26° C., but as a rule show no signs of so doing at 0° in daylight though they will begin at the same temperature as soon as it is dark or nearly dark. Below 0° they may or may not function in the dark, but have been observed to pass faeces at — 1.5° C.; they may be so completely frozen that no liquid shell-liquor can be detected, and yet recover in a short time, if thawed slowly, even though the mantle and surface of the body may have been frozen. Oysters, it was noted, are more sensitive to low temperatures than mussels and in general require different treatment in the purifying tanks.

It is an interesting fact that mussels appear to function as vigorously at low as at high temperatures, in spite of the fact that the cilia on the excised gill-filaments show a marked slowing-up of beat at low temperatures. The functioning of mussels in daylight at low temperatures is so uncertain that a rule was established in the cleansing procedure that the water must not fall below 39° F. (= 3,9° C) during at least one night of the treatment in the tank.

On another page the author gives reasons why the so-called liver may have at times an excretory as well as a digestive function.

In another and more important section of the report the author deals with "certain general considerations and suggestions regarding the sewage pollution of shellfish in its Public Health aspect". The existing system of defining pollution solely on the results of bacteriological analysis is attacked and condemned by means of experiments, observations and reasoned argument. It will probably be admitted by everyone that a living bivalve, taken from an estuarine situation, can never be stated dogmatically to be entirely free from those bacteria which are the same as, or indistinguishable from, those inhabiting the human intestine. Hence any "standard of purity" must be arbitrary; and the author proves that the published standards, upon which action is taken to condemn or condone shellfish and their beds of origin, are unsound. Regulations for the control of shellfish and their beds of origin may therefore be regarded as being in the melting-pot. The present time is therefore a convenient one in which to review the whole subject from an international as well as from a national point of view. In a problem of this kind it is certain that valuable information of an empirical kind is available, and can be collected — with mutual goodwill — and utilised for the solution of the general problem. This problem includes:—

1) the need for a clearly defined and recognised standard of purity in bivalves or, alternatively, the beds or other situations from which the bivalves are taken for consumption;
2) the classification of existing beds under recognised standards of purity or impurity;
3) a clear definition of the administrative body which is responsible for applying the standards.

In these investigations the reviewer has already suggested (Journ. Roy. San. Instit., Nov. 1928) that it would be advisable to include among the investigators in England, representatives of the Fishmongers' Company, the Ministry of Health, the Ministry of Agriculture and Fisheries and, for the topographical work, either a marine biologist or a hydrographer who is familiar with biological as well as hydrographical variations in estuarine situations.

The increasing sewage pollution in estuaries which formerly held a high standard of purity also calls for action from the point of view of Public Health and of relieving everyone concerned from anxiety.

The report is provided with a comprehensive list of contents; an excellent author and subject index, and bibliography; topographical maps of three important mussel beds; photographs of the tanks in the various stages of purification of mussels at Conway; photographs of critical bacteriological culture plates and original drawings of mussels in various stages of functioning. There is an Appendix by H. MARSHALL WEBB, on the formation of glucose in minced mussels and oysters on incubation. The author has well repaid the confidence and the magnificent support given to him by the Fishery Department of the Ministry of Agriculture and Fisheries.

J. N. CARRUTHERS. The Water Movements in the Southern North Sea. Part III. The Area off the Wash. (a.) The Flow of Water past the Inner Dowsing Lightvessel. Ministry of Agriculture and Fisheries. Fishery Investigations. Series II. Vol. IV. No. 6. London 1929. 36 S.

Wie immer mehr erkannt wird, hat der Reststrom eine erhebliche Bedeutung für die Verfrachtung von Fischlaich und die Schwankungen des Reststromes sind vielleicht sogar von Einfluss auf die Alterszusammensetzungen der Nutzfische. Da in dem Gebiet vor dem Wash-Busen Heringslaich in erheblichen Mengen abgesetzt wird, sind die dortigen Restströme fischereibiologisch von Interesse. Es sind deshalb von dem dort befindlichen Inner Dowsing Feuerschiff aus Reststrombeobachtungen mit dem Strommesser von CARRUTHERS gewonnen worden in gleicher Weise wie auf dem Varne Feuerschiff (vergl. Journal du Conseil IV, S. 234—236), also in 6 Faden Tiefe. Die Beobachtungen begannen wie auf Varne F. Sch. im Juni 1926 und wurden bis Oktober 1928 durchgeführt, sie erstrecken sich demnach über einen Zeitraum von mehr als zwei Jahren. Im Oktober 1928 wurden die Arbeiten abgebrochen, dafür wurden auf dem 26 Seemeilen ostsüdöstlich gelegenen Cromer Knoll Feuerschiff gleiche Beobachtungen begonnen, die ebenfalls zwei Jahre hindurch fortgesetzt werden sollen. Die Arbeiten auf Inner Dowsing Feuerschiff sind also jetzt abgeschlossen, ihre Bearbeitung liegt in oben genannter Veröffentlichung vor. Die gesamten Beobachtungen sind für den ganzen Zeitraum von 751 Mondtagen gleich 777 gewöhnlichen Tagen veröffentlicht; die einzelnen Messungen beziehen sich meist auf zwei, selten auf einen oder drei Mondtage. Zur Gewinnung einer Übersicht über die Ergebnisse wurden die mittleren Restströme für jeden Monat und jede einzelne Jahreszeit berechnet sowie ausserdem