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Als Konkurrenz zur Weißblechdose wurden im Sektor Vakuumverpackung einige Verbundfolien entwickelt, welche neben der erforderlichen Undurchlässigkeit sehr gute mechanische Eigenschaften aufweisen (Zähigkeit, Berst- und Reißfestigkeit, Dehnungsverhalten). Die höchste Gas- und Wasserdampfdichtigkeit liefern Dreischicht-Verbundfolien, in welchen Aluminiumfolie der Stärke 0,012—0,015 mm auf Filme mit hoher Lastaufnahme und geringer Dehnung kaschiert sind (z. B. Polyester, Cellophan, orientiertes Polypropylen), während die andere Folienseite mit einer thermoplastischen, gut heißsiegelfähigen Schicht (bevorzugt PAe) versehen ist. Aus solchen Verbundfolien hergestellte Raumbeutel halten ein Vakuum von 10—15 mm Hg Restdruck während mehrerer Monate; dies eröffnet die Möglichkeit, gemahlenen Bohnenkaffee 1 Jahr und länger ohne Qualitätseinbuße in solchen Vakuumpackungen zu lagern.

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Vacuum Packaged Cured Meats *

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Introduction

Vacuum packaging ist a process which lends itself successfully to the packaging of a number of foods. The process as applied to cured meats may be divided into two main divisions, according to whether the product is to be packed in the

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raw state or cooked. In either case, there are four very important aspects to be considered, namely, the colour of the meat, its eating quality, its bacteriological condition and its keeping properties.

In order to understand the problems of vacuum packaged cured meats properly, it is necessary to consider briefly the nature of the curing process.

Fresh meat is a highly nutritious but very perishable food. It is therefore hardly surprising that primitive man sought some means of preserving the products of his most profitable hunting expeditions to ensure a supply for the leaner times when he was less fortunate. One of the most successful methods which he tried was to treat the raw flesh with salt. Another was to dry and smoke it over a slow-burning wood fire. Such practices are thousands of years old. According to *Jensen* (1), however, it was not until the late Middle Ages that saltpetre began to be added deliberately to the curing salt. The origin of this practice seems to be obscure, but it is almost certain that saltpetre was present as an impurity much earlier than this. At any rate, it was discovered that with the aid of this substances, effective preservation could be achieved using a smaller quantity of salt, thus making the cured meat more palatable whilst at the same time imparting to it an attractive red colour. Still further enhancement of both keeping properties and flavour were produced by smoking the meat cured by this process. Thus by a slow process of evolution were formed the basic principles of the method of curing meats, which is still largely in use today for the production amongst other commodities of bacon.

Bacon made by this traditional curing process takes at least three weeks to produce and has been found as a result of long experience to be stable and to keep well if kept reasonably cool and stored in large pieces or sides. However, it deteriorates fairly rapidly when sliced, and moreover, the method of manufacture is relatively slow by modern standards.

Vacuum-Packaged Bacon

The transition from this traditional bacon to a more stream-lined prepackaged product has not been easy and many of the problems have by no means been solved. It is only within recent decades that true nature of the changes which occur during the curing process and the part played by bacteria have begun to be understood, and it is only within the last two or three years that the real nature of some of the chemical reactions associated with colour production and the part played by the enzyme systems of the meat itself have been elucidated, largely as a result of the work of *Walters* and *Taylor* at Leatherhead. However, as long ago as 1901, *Haldane* (2) showed that the colour of cured meat was due to a pigment nitroso-myoglobin, formed by the reaction between nitric oxide and the reduced form of the muscle pigment, myoglobin.

The steps involved in the conversion of the saltpetre to nitric oxide may be outlined as follows:

1. Reduction of nitrate to nitrite by the action of the bacteria in the curing brine. Since this process is apt to be rather slow at first in a fresh brine. it became usual to add a quantity of sodium nitrite to a fresh pickle in addition to the orther ingredients.

2. Reduction of the nitrite to nitric oxide which appears to be brought about at least to some extent by the enzymes of the meat itself, in association with certain reducing systems which are present in the tissues.

The nitroso pigment is, however, not very stable and is readily oxidised, especially in the presence of light. *Walsh* and *Rose* (3) have in fact demonstrated three separate oxidative michanisms by which it is converted to a brown pigment — met-myoglobin. Two of these are by direct combination with oxygen and the third by reaction with excess nitrite. The acceleration of the oxydation by visible light of many wavelengths and the impossibility of keeping the product in the dark at the point of sale led quite naturally to the alternative of excluding the oxygen and hence to the choice for this type of product of the vacuum-pouch made of materials which are highly resistant to the penetration of oxygen and water vapour. The most commonly used pouch is made of polythene/cellulose laminate, the cellulose being either normal moisture-proof of saran-coated. Polythene/polyester film is also being used. Thus, by excluding oxygen, the colour of the bacon is preserved without the need to keep the packages in the dark.

The Microbiological Aspects

However, this leads to further difficulties. Traditionally cured bacon carries a large load of micro-organisms from the curing brine, including those responsible for the reduction of the nitrate to nitrite, as well as a considerable excess of nitrate. This process is therefore able to continue in the package and indeed frequently appears to be accelerated, producing sometimes quite bhigh concentrations of nitrite. Figures well in excess of 2000 p. p. m. have been recorded by *Kitchell* (4), although amounts of 1000 p. p. m. or more are known to be liable to cause oxydation of the pigment as described above. In addition, there is the health aspect to be considered. Nitrite itself is toxic, especially to young children and there is at present a Statutory limit in the United Kingdom (5) of 500 p. p. m. in uncooked cured meats, from which, however, bacon is at present excluded.

Excessive nitrite production may be controlled in one of three ways; by limiting the amount of nitrate in the traditional curing pickle, by keeping the storage temperature low, (below 10 ° C) or by departing al Together from the traditional pickle and using one which contains salt, just sufficient nitrite to effect the cure and no nitrate.

The effects of such changes in the traditional cure have yet to be fully assessed. It soon became clear, however, that some modifications of the traditional methods would be necessary to produce a bacon suitable for vacuum packaging. At the same time, it was desirable if possible to speed up the process in line with modern methods of production. This led to at least one bold departure from the conventional process, namely, the slice-curing process, invented by Unilever which is described elsewhere (6) and which has been in commercial operation for several years. In this, the meat is pre-sliced in as hygienic a manner as possible, dipped for a short time in a sterile brine containing sodium nitrite, smoked briefly if desired, and immediately vacuum packaged. After maturing for a few hours at room temperature, the bacon is of good colour and ready for sale. It is believed that other, perhaps less drastic modifications of the traditional curing process are in use, but these have not been described.

One of the most important considerations which was mentioned at the beginning of this paper, is organoleptic quality, especially flavour. It has been known for a long time that nitrite plays a considerable part in the development of the characteristic bacon flavour, Smoking also plays its part. However, it would be idle to suggest that there are not many other subtle factor involved, such as the effect of the brine bacteria and their enzymes, and for this reason, it is probably very unlikely that any form of vacuum-packaged bacon will ever be strictly comparable in flavour with that of the traditional product. This is probably a case where the public will be found to accept the change for the sake of the extra convenience of a product in pre-packaged form.

The bacteriology of traditionally cured bacon is altered considerably by vacuum packaging. In curing, the main load of micro-organisms is derived from the curing pickle where they are present in large numbers and considerable variety, except that they are mainly salt-tolerant and include large numbers of micrococci and smaller numbers of lactobacilli. However, these are confined mainly to the surface of the bacon which dries to some extent, either naturally as in the case of unsmoked or green bacon, or hastened by smoking. In the latter case, the constituents of the smoke are deposited on the bacon and have some preservative effect. The surface relative humidity of the bacon as normally stored is generally below that which would permit rapid bacterial growth. Such growth as does take place is mainly of aerobic organisms.

In the vacuum package, the surface of the meat does not dry out and consequently, conditions of much higher relative humidity exist. The state of lowered oxygen tension which is responsible for the good preservation of colour, encourages the growth of putrefactive anaerobes and facultative anaerobes such as the lactobacilli, and suppresses the growth of the more aerobic micrococci. As a result, there is frequently a tendency for the bacon to become cheesey in flavour upon prolonged storage (*Cavett* [7]). When the packaged bacon has been pre-sliced, there is a spreading of the organisms from the outside of the meat over the freshly cut surfaces. The nett result according to *Ingram* (8) is that bacteriologically speakting the storage life of sliced bacon is not greatly extended by vacuum packaging.

One important aspect of the bacteriology of these products relates to food-poisoning. The organisms mainly implicated are of three types, the salmonellae or typhoid/paratyphoid group, the spore-bearing anaerobes, which include the extremely deadly *Clostridium botulinum*, and the staphylococcal group, some of which may be responsible for severe digestive upsets.

The salmonellae differ from the other groups in that they are intestinal organisms and are capable of producing an active infection in the victim. The members of the other two groups produce exo-toxins when they multiply in food so that poisoning occurs when the food is eaten. Thus, for salmonella food poisoning to occur, it is necessary only that some small number of living organisms should survive on the food and be eaten by the consumer. In the case of the other two groups it is necessary for the bacteria concerned to have multiplied in the food and to have produced their toxins in order to cause poisoning.

Salmonellae grow best around 37 ° C but they are able to survive at much lower temperatures, and it has been shown that they can exist in bacon curing brines and that they can survice, though without multiplication, on the surface of the vacuumpacked bacon. Survival is best at low temperatures. Since they are intestinal organisms, they are quite likely to find their way in small numbers from the slaughter houses, through the traditional curing brines to the final product. However, food-poisoning is unlikely through this cause, as bacon is normally cooked before being eaten and the organisms are easily killed by heat The risk which is run is no worse at any rate than that which the housewife runs when she handles fresh butchers' meat in that there is a possibility she might contaminate some other food by transferring organisms on her hands or the utensils she uses.

The staphylococci, of which *Staph. aureus* is the principal offender is the cause of various lesions such as boils and is also commonly present in the nose or throat of quite healthy individuals. It is therefore likely to gain accell to the bacon from carriers at the slicing and packaging stage. It has been shown to be capable of growing and multiplying on vacuum packaged bacon at 25 ° C, but not at 5 ° C. *Ingram* (9), however, has shown that although these organisms will grow quite readily on sterile bacon, if the normal brine «flora» is present, this multiplies faster than the *Staph. aureus* and suppresses it. It appears from this point of view, therefore, that as far as bacon is concerned, the heavy load of brine organisms produced by the traditional type of cure may be a desirable feature in the vacuum packaged product.

There is also evidence that nitrite in amounts of the order of 100 p. p. m. is inhibitory to *Staph. aureus*. Since the active agent in this case has been shown to be undissociated nitrous acid, it follows, and has indeed been proved that it is desirable that the meat should be of low pH for this effect to be manifest. At high pH values, amounts of nitrite considerably in excess of 100 p. p. m. are necessary to inhibit the organism.

The toxin of *Staph. aureus* is fairly stable to heat and is said to resist boiling for 30 minutes, so that it is unlikely to be completely destroyed even by normal cooking, although the organism itself is readily destroyed. It is conceivable, therefore, that in certain circumstances, e. g., if there is a deficiency of nitrite, *Staph. aureus* could constitute a hazard in vacuum-packaged bacon, especially as the bacon would not necessarily be affected organoleptically as a result of its growth. Storage of the bacon below 10 ° C or the careful control of the pH and nitrite content would, however, presumably act as an adequate safeguard.

The third group of pathogens, the botulinum group differs from the others in forming spores which are very heat-resistant, and in being very strict anaerobes. Since they are soil organisms, they also are liable to be introduced into bacon as contaminants from the slaughter-house. It is by no means certain that at least one of the strains of this organism would not be capable of developing on vacuum packaged bacon, probably with toxin production, although this has never been known to occur in spite of the very large commercial turnover of this commodity. The known inhibiting factors include reduction of the pH to 4.5 or below, raising the salt content to not less than 10 g NaCl per 100 g water, reducing the a_w (water activity) to below 0,94 or storage below 3 ° C. None of these conditions is normally fully met in vacuum-packaged bacon. There are indications however that other inhibitory factors exist, such as nitrite and possibly also nitrate, but insufficient is known about the effect of these on botulinum growth and toxin formation. Fortunately, even the most stable of the botulinum toxins is destroyed by 10 minutes at boiling point, so that adequate cooking of the bacon is an important safeguard in this case.

Cooked Cured Meats

In the case of vacuum packed cooked cured meats, very much the same considerations apply as for the uncooked meat, with the one important exception that these products are intended for immediate consumption without further cooking after removal from the pack.

In these products, the cooking process may promote some loss of salt and nitrite and may cause the pH to rise slightly so that the ionisation of the nitrous acid is increased. All of these changes tend to faveur the growth of undesirable organisms. Since, in addition, most of the normal spoilage flora will have been destroyed, there remains a clear field for the development of any contaminants such as pathogens conveyed by the hands of the workers who slice and package the product, or of viable spores of *Cl. botulinum* which may be present, having survived the curing and cooking process. Experience with these pathogens has shown that food rendered toxic by their action does not necessarily show any outward sign of deterioration. The risks, therefore, are very muchhigher with this type of product, than with pre-packaged uncooked cured meats. Although the risks may still appear to be quite small, it is quite impossible to estimate them with any accuracy, and even a chance of one in a million is greater than food manufacturers can afford to take.

A considerable amount of research is being carried out by The British Food Manufacturing Industries Research Association amongst other organizations, to define more closely the precise conditions of processing and packaging which will make pre-packaged cooked cured meat products safe for the consumer, and some progress is undoubtedly being made. Meanwhile, there are only two courses open to manufactures. The first is to store such products always under refrigeration (i. e., below 3 ° C). This is satisfactory so long as the wholesaler, retailer and public will cooperate. The chain may be shortened by the manufacturer cutting out the wholesaler and dealing directly with specially selected retailers. This leaves the public as the main obstacle to success. since the housewife may fail to heed the warning on the label. The British housewife is not yet as refrigerator-conscious as her American counterpart, yet even in America recently, there have been recorded cases of deaths from botulism attributed to eating vacuum-packaged smoked fish which was not stored under refrigeration.

The secound alternative, which is to subject the sealed package to a heat-treatment akin to pasteurization, or even sterilisation, seems to be safer, but may not suit all types of product. However, it is being actively investigated, and as a result of the research being carried out, it may be possible at a later stage to specify a mild treatment of this type which will render even the most delicate types of product safe for the consumer without unduly spoiling their sales appeal.

This short paper serves to illustrate the difficulty encountered in trying to adapt traditionally cured meat products to suit modern methods of packaging and marketing. It is often not until an exercise such as this is undertaken that the basic principles behind the stability of the traditional product become fully revealed.

Summary

The origin and nature of the traditional process of curing meat are briefly described, with particular reference to bacon and its stability. In the vacuum-packed product, many of the factors affecting stability are subject to modification. These changes are discussed in relation to microbiological spoilage and foodpoisoning risks in both cooked and uncooked cured meats.

It is concluded that although the risks are extremely small in the case of an uncooked product such as bacon, there is apparently a distinct hazard in the case of vacuum-packed cooked cured meats unless these are either stored under refrigeration or given a heat-sterilising treatment after packaging. It ist hoped that further work at present in progress will throw more light on this complex subject.

Résumé

L'origine et la nature du procédé traditionnel de traitement de la viande pour la conserver sont brièvement décrits, en se référant particulièrement au lard et à sa stabilité. Dans le cas de lard conservé sous vide dans des emballages appropriés il est recommandé soit de l'entreposer dans des frigorifiques soit de le stériliser par chaleur, après emballage.

Zusammenfassung

In dieser Arbeit werden Ursprung und Natur der herkömmlichen Verfahren zur Behandlung des Fleisches zwecks Konservierung beschrieben unter besonderem Hinweis auf den Speck und seine Haltbarkeit. In den Produkten, die unter Vakuum verpackt werden, sind verschiedene Faktoren, welche die Haltbarkeit beeinflussen, gewissen Veränderungen unterworfen. Letztere werden besprochen im Zusammenhang mit dem mikrobiologischen Verderb und der Gefahr der Lebensmittelvergiftung bei gekochtem und ungekochtem Fleisch.

Es wird die Schlußfolgerung gezogen, daß die Gefahren bei ungekochten Produkten, wie z. B. Speck, sehr klein sind. Für gekochte Fleischwaren, die unter Vakuum verpackt werden, ist es empfehlenswert, die Produkte entweder im Kühlschrank zu lagern oder sie einer Wärmesterilisation nach Verpackung zu unterziehen. Es ist zu hoffen, daß in einer weiteren Publikation noch mehr Klarheit in dieses komplizierte Gebiet gebracht werden kann.

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