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ALTERNATIVES TO NITRATES AND NITRITES IN ORGANIC MEAT PRODUCTS

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1 INTRODUCTION

A requirement of Commission Regulation (EC) 889/2008 (EC 2008a), which laid down detailed rules to further elaborate Council Regulation (EC) 834/2007 (EC 2007a) on organic production and labelling of organic products, is a re-examination of the use of nitrates and nitrites in cured organic meats with a view to withdrawing these additives by the end of 2010.

In order to inform Defra of the possible effects of this action in the UK, this Defra funded project (Defra Project Reference OF0389) includes a literature review of alternatives to nitrates and nitrites in meat products, an analysis of the microbiological issues relating to nitrates and nitrites in meat products with regard to shelf life and pathogenic organisms and a consultation with industry about the implications of this legislation.

2 THE LEGAL POSITION

The legislative arena in which this issue exists is addressed here by reference to the pertinent legislation, the background to its development and consideration of the legal position of possible alternatives to the use of nitrates/nitrites

2.1 The current situation

Renewed rules on the organic production and labelling of organic products were introduced in the EU on 1 January 2009 by virtue of Council Regulation (EC) No 834/2007. (EC 2007a) This repealed the original organic Regulation, Council Regulation (EEC) No 2092/91. Council Regulation (EC) No 834/2007(EC 2007a), while laying down the basic rules, did not cover all the detailed provisions, such as on the use of additives, which the outgoing 1991 Regulation had covered. These more detailed rules were added, before 1 January 2009, by another Regulation, Commission Regulation (EC) No 889/2008 (EC 2008a) laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control.

2.2 Legal background to use of nitrites and nitrates in organic products

When first published, the 1991 organic Regulation did not include rules for organic production of livestock and livestock products. Such rules were introduced later and applied from August 2000, although which additives were permitted to be used in organic products of animal origin was initially left in the hands of individual Member States. Subsequently, from December 2007, the list of additives for organic products of animal origin was harmonised and this harmonised list contained sodium nitrite (E250) and potassium nitrate (E252). These additives were permitted to be used in organic meat products at up to particular limits in relation to each of ingoing and residual levels (see Commission Regulation (EC) No 780/2006 (EC 2006) amending Annex VI to Council Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs). Regulation 780/2006 (EC 2006) included a proviso on the usage of each of sodium nitrite and potassium nitrate as follows:

‘This additive can only be used if it has been demonstrated to the satisfaction of the competent authority that no technological alternative giving the same sanitary guarantees and/or allowing to maintain the specific features of the product, is available’

Further, although the Regulation only applied from 1 December 2007, it contained a statement that the inclusion of sodium nitrite and potassium nitrate in the list of permitted additives for organic meat products was to be re-examined before 31 December 2007, with a view to limiting or withdrawing the use of these additives.

A February 2008 amendment to the 1991 Regulation (Commission Regulation 123/2008) (EC 2008b) reported that a panel of independent experts had, in a report of July 2007 (see Annex 1), recommended eliminating sodium nitrite and potassium nitrate from organic meat products ‘within a reasonable time scale’. In order to allow an assessment of the implications of removing them to take place, the panel recommended that the additives should be permitted until 31 December 2010. It was said that the assessment should take account of the extent to which the Member States had found safe alternatives to nitrites/nitrates, and of their progress in establishing educational programmes in alternative processing. The 2008 amendment therefore called for the permitted usage of sodium nitrite and potassium nitrate to be re-examined before 31 December 2010 with a view to their withdrawal. The re-examination was to take account of the efforts made by Member States to find safe alternatives to nitrites/nitrates and in establishing educational programmes in alternative processing methods and hygiene for organic meat processors/manufacturers.

It was against this background, with a firm pre-existing desire to withdraw sodium nitrite and potassium nitrate from organic meat products, that the new legal regime replaced Regulation 2092/91 from 1 January 2009. Regulation 889/2008 retains the two additives, in Annex VIII, as substances which may be used for organic meat products, at up to 80mg/kg indicative ingoing amount and 50mg/kg maximum residual amount, as before. Again there is the proviso in each case that

‘This additive can only be used, if it has been demonstrated to the satisfaction of the competent authority that no technological alternative, giving the same guarantees and/or allowing to maintain the specific features of the product, is available’

In addition, Article 27(3) states:

The use of the following substances listed in Annex VIII shall be re-examined before 31 December 2010:
(a) Sodium nitrite and potassium nitrate in Section A with a view to withdrawing these additives;
(b)...
(c).....
The re-examination referred to in point (a) shall take account of the efforts made by Member States to find safe alternatives to nitrites/nitrates and in establishing educational programmes in alternative processing methods and hygiene for organic meat processors/manufacturers.

2.3. Legal position of possible alternatives to nitrites/nitrates

The list of additives permitted for use in the production of processed organic food, as laid out in Annex VIII Section A to Regulation 889/2008, is basically a subset of the additives permitted in ordinary foods under the general additives controls.

Regulation 834/2007 states:

‘This Regulation shall apply without prejudice to other community provisions...’

and it should therefore be assumed that, in relation to additives permitted in processed organic food, all the general additives controls apply, including the definition of an additive and that any permitted additive should comply with its associated purity criteria.

Alternatives to nitrite or nitrate in processed organic foods could be other additives, or normal ingredients of foods which have the desired technological effects.

If they were other additives, they could be from the current Annex VIII Section A permitted list or, if none were suitable, further additives added to Annex VIII Section A from the lists of generally permitted additives, or even additives not previously authorised for use in any foods in the EU.

If they were normal ingredients of foods, but used in this case for their technological functionality, they would need to be added to the Annex VIII Section B list of ‘processing aids and other products, which may be used for processing of ingredients of agricultural origin from organic production’. Additives controls would not apply to the use of these materials.

The definition of a ‘food additive’ from Regulation (EC) No 1333/2008 (EC 2008c) of 16 December 2008 on food additives is as follows:

‘food additive’ shall mean any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food, whether or not it has nutritive value, the intentional addition of which to food for a technological purpose in the manufacture, processing, preparation, treatment, packaging, transport or storage of such food results, or may be reasonably expected to result, in it or its by-products becoming directly or indirectly a component of such foods.

It is worth noting that, driven by the desire to achieve ‘clean labels’ for all types of foods, the replacement of additives with non-additive ingredients having the same technological function is a major concern for many businesses. This is not a straightforward exercise since candidate ‘non-additive ingredients’, if they are not normally consumed as foods in themselves, are likely to be viewed by enforcement interests nevertheless as additives, and indeed as non-permitted additives, if they are not listed in the additives legislation. For instance, in its guidance on the general additive provisions relating to the use of nitrites and nitrates in meat products, the Food Standards Agency states:

‘The indirect addition of nitrates to foods via extracts of vegetables such as spinach or celery should be considered an additive use, and not a food use (i.e. the extract is being added for preservation as it contains a standardised level of nitrate) and consequently such use would not be permitted by Directive 95/2/EC as these extracts have not been approved as preservatives.’

(Directive 95/2/EC (EC 1995) is the miscellaneous additives Directive, now replaced by Regulation (EC) No 1333/2008 of 16 December 2008 on food additives, although the lists of permitted additives in Directive 95/2/EC continue to apply for the time being).

Similarly, in the Summary Record (Sanco 2006) of 14 December 2006 meeting of the Standing Committee on the Food Chain and Animal Health, the following comment is made:

'Spinach extract containing high levels of nitrate used in sausages: Outcome of discussion at additives working group/for endorsement.

It has been reported that some manufacturers of meat products were using standardised spinach extracts containing high levels of nitrates. Furthermore such products are labelled to imply that they contain no added preservatives. It has therefore been questioned whether such use should be considered as that of a food additive as it may exert a preservative and/or colour fixing effect.

This issue was discussed at a meeting of the Working Party of Governmental Experts on Food Additives on the 22nd September 2006 and the outcome of the meeting was endorsed by the Standing Committee. Member States considered that such a practice would be a deliberate use of a food additive if used for the intended technological purpose of preservation in the final food. Consequently such a use of a food additive should comply both with the food additive legislation and also be labelled in compliance with the appropriate food labelling legislation.'

It follows from these official views that vegetable extracts, selectively extracted to give materials with a relatively high level of nitrate, are additives and need to pass through the additives approval process before they can be used in foods. As far as processed organic foods are concerned, again these materials would need to be approved before they could be used. It would seem likely that the sequence would be that the materials would pass through the general additives approval process first, and then be considered for use in organic products. However, there appears to be no legal impediment to relevant materials being approved initially for organic products, to satisfy a special need in this sector, prior to more general approval perhaps being considered. It is unlikely that any approval undertaken with organic products specifically in mind would be any quicker than the general approvals process. The approvals process for additives is nevertheless now considerably more rapid than it has been in the past.

2.4. Conclusion

Throughout the period that sodium nitrite and potassium nitrate have been listed in the harmonised EU organic controls, the listing has been coupled with statements that they should only be used where suitable alternatives are not available and that their usage should ultimately be withdrawn, subject to alternatives being available and producers being in a position to use suitable alternative processing methods. The current final date for examination of whether the additives can practically be withdrawn is 31 December 2010.

Any more acceptable alternative materials would still be subject to the principle laid down in Regulation 834/2007 that the use of food additives and of non-organic ingredients with mainly technological functions should be restricted to a minimum and to cases of essential technological need. Authorisation of any replacement materials would be required. Any replacement product which was not an additive would need to be authorised and listed in Annex VIII Section B of Regulation 889/2008, while a replacement which was an additive would need to be authorised and listed in Section A of the same Annex.

Materials selectively extracted from vegetable materials and containing relatively high levels of nitrates would still be being used for a technological function and would be considered to be additives. If they were not generally listed already as permitted food additives, any authorisation would need to include both general additive considerations of safety, technological need and the potential to mislead consumers, and specific organic considerations.

The organic authorisation procedure for additives and other materials used for a technological purpose is laid down in Article 21(2) of Regulation 834/2007 and involves the sending of a dossier of reasons for the inclusion of the intended new material to the Commission and Member States. A time-limited procedure then ensues.

3 NITRATE AND NITRITE

3.1 Historical development of curing

The preservation of meat by curing has been practiced for a long time. The origin of nitrate usage in the form of saltpetre is lost in time but preservation of meat with salt has been carried out for centuries. The ancient Greeks used salt to preserve fish and the Romans preserved fish and meat with pickles containing salt and other ingredients. (Pegg and Shahidi, 2000)

With increasing use of salt as a preservative for meat, a preference developed for salts that developed a pink colour and special flavour, rather than a less attractive grey colour. This pink colour and special flavour was attributable to the nitrate impurities in the rock salt which were reduced to nitrite by the reducing activity of the muscle post-mortem.

Curing evolved during medieval times to include the development of sweet cures as sugar became an available commodity and meat curing was understood to include the use of saltpetre. By the end of the nineteenth century, various methods of curing (dry cures, wet cures and combinations of both) had been developed.

The traditional processing of dry-cured meat was passed from generation to generation and ancient practices involved rearing pigs at home before slaughtering them around the end of autumn or early winter i.e. the start of the cold weather. Salting and post-salting was carried out during the winter months and ripening and drying took place in spring and summer respectively. Production sites were usually in middle-high mountains where the climate was cool and dry and favoured the drying process (Toldra, 2002). Dry curing involves rubbing the cure ingredients over the surface of the meat and over time they become solubilised in the natural moisture of the muscle tissue. Penetration of the cure into the meat is slow and usually more than one application of cure salts is necessary. Between treatments, the meat is hung up in a cool dry atmosphere and moisture is slowly lost from it. A sequence of restacking the dry meat helps complete the cure, after which excess cure is washed off and the material is subjected to refrigeration followed by drying to evenly distribute the cure then ripen the product. This method of salting is still used in some modern processing facilities in Europe.

Nowadays, dry curing tends to be used for specialty European type hams such as Spanish Serrano, Iberian, Parma hams and prosciuttos and these products are usually eaten in the raw state. Most modern factories have available to them chambers with computer controlled temperature, air speed and relative humidity. Computers are also able to reproduce the four seasons of the year in drying chambers. Parma ham processing is tightly controlled and regulated and the use of nitrate was banned in1993. There are strict control measures throughout the process to ensure product safety (Toldra, 2002). The colour is thought to be due to a zinc–protoporphyrin IX pigment complex that develops throughout ageing and ripening. (Wakamatsu et al, 2004)

Immersion curing involves whole cuts of meat being immersed in brine solutions containing curing agents, and some traditional products, such as Wiltshire cured products, rely on the use of “live” brines with carefully controlled microflora.

Injecting meat with brine via a perforated needle has greatly reduced the length of time required to cure products and multi-needle injector machines are now commonly used to produce cured products. Smaller artisan producers may use arterial pumping where cure is distributed through the arteries of the meat, and stitch pumping which involves injecting the meat muscle with a single needle and the natural channels present in the tissue help distribute the cure.

3.2 The role of nitrate and nitrite

Historically, sodium or potassium nitrate was used as a meat-curing agent. Nitrate is converted to nitrite by nitrate-reducing bacteria and it was found that it was nitrite that increases colour change and that smaller amounts are needed compared to nitrates (Gray and Pearson, 1984). Nitrite also confers anti-microbial properties and other curing effects on meat (Jones and Betts, 2009, Sebranek and Bacus, 2007).

A factor in the formation of N-nitrosamine is the residual nitrite concentration. Nitrate is therefore not used in most curing processes to control residual nitrite concentration, as it is more difficult to control the amount of nitrite formed (Sebranek and Bacus, 2007). However, some traditional curing processes, such as Wiltshire, use “live” brines where active controlled microbial growth takes place, converting nitrate to nitrite.

Nitrite has many important functions in meat curing including producing cured meat colours, contributing to flavours, inhibiting microbial growth and slowing rancidity (Gray and Pearson, 1984). The chemistry of nitrite in cured meat is a complex issue as nitrite is a very reactive compound, reacting with a wide range of substrates (Sebranek and Bacus, 2007). Microbiological implications of the removal of nitrite have will be discussed in section 4 of this report.

3.3 Cured meat colour

The main pigment associated with meat colour is myoglobin. The colour of meat is dependent on the amount of myoglobin present and the chemical status of the pigment. Myoglobin can be found in three forms depending on whether the pigment has been oxidised or reduced. In raw meat myoglobin is a purple-red colour, while oxymyoglobin is bright red and metmyoglobin is brown. Oxymyoglobin can be formed from oxygenation of myoglobin, and Metmyoglobin is formed by oxidation of myoglobin (Pegg and Shahidi, 2000).

With cured meat, nitrosylmyoglobin is responsible for the red colour of raw cured products. It is formed from the reaction of myoglobin with nitric oxide. Sodium nitrite is the usual source of the nitric oxide and in solution the nitrite ion exists in equilibrium with undissociated nitrous acid. Nitrous acid is thought to decompose in slightly acid conditions to give nitric oxide. Nitrite is also an oxidising agent which rapidly converts myoglobin to metmyoglobin, which is then reduced to nitrosyl metmyoglobin. Conversion of myoglobin to the nitrosyl form is incomplete, not very consistent and may vary between about 35% and 75%, with input nitrite 100-150ppm, in different samples of meat (Ranken, 2000). During heating, nitrosyl myoglobin is denatured to pink nitrosyl myochromogen, also described as the Cooked Cured Meat Pigment (CCMP). Nitrite fixes the pink colour of cured products rather than imparting a colour itself (Pegg and Shahidi, 2000).

The intensity of cured meat colour is directly related to the concentration of nitric-oxide stabilised myoglobin in the muscle, not the nitrite level. For example if cured ham and corned beef are cured with the same amount of nitrite, the corned beef has a more intense cured meat colour than the ham (Pegg and Shahidi, 2000)

The addition of ascorbic acid, ascorbate or erythorbate can increase the conversion of nitrite to nitric oxide (reduction reaction) and consequently speed up the reaction of nitric oxide with myoglobin (Sebranek and Bacus, 2007, Pegg and Shahidi, 2000) Ascorbate is believed to improve the efficiency of curing and the reaction is thought to represent a saving of approximately one-third of the nitrite. Ascorbate also helps to remove traces of oxygen, which inhibits cured colour development (Ranken, 2000)

.

Sebranek and Bacus (2007) report that residual nitrite levels of 45-119ppm are sufficient to produce cured meat colours, while Tichivangana et al (1984) report that levels down to 10mg/kg of nitrite in lean meat will produce acceptable colour and flavour. Data from Ranken, (2000) suggests that bacon with low or zero nitrite at time of frying may be grey after cooking and that nitrite levels needed for colour formation and stability in bacon need to be around 10-20ppm in the heated bacon at time of cooking.

The level of nitrite required for colour fixation is dependent on the concentration of myoglobin in the tissue and this in turn is affected by species, sex, age, muscle type, age and nutrition. Walsh et al, (1998) considered colour stability over time to be dependent on residual nitrite., with residual nitrite remaining in the tissue after curing (including cooking) thought to act as a reservoir for nitric oxide for continued stabilisation of colour pigment (Dryden and Birdsall, 1980)

The chemistry of nitrite curing is complex and not yet fully understood. A more comprehensive review can be found in Pegg and Shahidi, 2000

3.4 Cured meat flavour

The production of cured meat flavour is possibly the least understood area of nitrite chemistry (Sebranek and Bacus, 2007). One element of the flavour may be due to the effect of nitrite on lipid oxidation. Gray and Pearson (1984) state that nitrite has been shown to delay rancidity and lipid oxidation in meat products. Lipid oxidation causes the production of “off” or rancid flavours in the product. It is thought that the antioxidant effect of nitrite is similar to that which produces colour, by reducing iron in the haem compound to a form which does not promote oxidation (Pierson and Smoot, 1982).

The use of other antioxidants, however, does not result in similar flavour development when compared to products containing nitrite, showing that the flavour produced is more than a simple antioxidant effect (Sebranek and Bacus, 2007). It has been shown that nitrite levels down to 50ppm can have an antioxidant effect, reducing TBA (thiobarbituric acid, a measure of rancidity) values by up to 64% for beef, pork and chicken (Sebranek and Bacus, 2007).

Many studies have investigated the volatile compounds produced from cured meat products and are described by Pegg and Shahidi (2000). An article by Feiner (2007) states that cured meat flavour is developed from nitrite components reacting with sulphuric material which is present in meat muscle. In Wiltshire bacon, Tichivangana et al (1984) summarise that there was a linear relationship between the bacon flavour and the nitrite concentration in the curing brine. Similar studies have shown increased panel acceptance scores of products as nitrite concentration increases (Pierson and Smoot, 1982).

Research studies summarised by Pegg and Shahidi (2000) do state that an acceptable bacon can be prepared without nitrite, with sodium chloride being more important than nitrite in cured meat flavour. When considering the flavour implications of replacing nitrite in meat products, acceptable replacements may depend on the native processes and usage. Examples include the use of smoking in some countries for cured meat products which can mask unwanted flavours and act as an antioxidant, reducing lipid oxidation (Tichivangana et al, 1984).

3.5 Why reduce nitrate and nitrite in meat products?

Nitrate and nitrite are naturally occurring ions and human exposure to nitrate is mainly from the ingestion of food. Important sources of nitrate in the diet are vegetables, fruit and processed meat products. Ingested nitrate is excreted in the saliva and reduced to nitrite mainly by oral bacteria. Under acid conditions in the stomach, nitrite ions can react readily with nitrosatable compounds, especially secondary amines and alkyl amides, to generate N-nitroso compounds, several of which are potential human carcinogens (IARC, 1987). At a meeting of scientists at the International Agency for Research on Cancer (IARC) in France in 2006 to assess the carcinogenicity of ingested nitrate and nitrite (IARC, 2006), the working group concluded that, overall, “ingested nitrate or nitrite, under conditions that result in endogenous nitrosation, is probably carcinogenic to humans (group 2A)” (IARC 2010, in press). Nitrosation reactions can be inhibited by the presence of vitamin C or other antioxidants. Some epidemiological studies assessing the risk of cancer in people who had a high intake of nitrate or nitrite and and a low intake of vitamin C (which could result in endogenous formation of N-nitroso compounds) were weighted more heavily than studies without this information by the working group (IARC, 2010, in press).

Nitrosamines became a major concern in the 1960s and 70s with much of the research on alternatives to nitrite starting around the 70’s. However, changes in manufacturing methods in the 1970’s resulted in reducing the amount of nitrite required. Evidence that nitrite levels in usage are decreasing was shown by research in the USA by Cassens (1997), which concluded that the residual nitrite content of cured meat at retail was 10ppm, representing an 80% reduction since the 1970s.

There have been studies which suggest positive health benefits from the consumption of nitric oxide as it is important in physiological functions and helps to regulate blood pressure (Cassens, 1997, Daniells, 2007). However, in certain cured products nitrosamines can be formed on cooking at high temperatures (Shahidi and Pegg, 1993).

Following a recent request from the European Commission, the EFSA Panel on Food Additives and Nutrient Sources added to Food was asked to assess the data provided by the Danish authorities, in particular whether this information, or any other new scientific developments, indicated that there was scientific evidence for a revision for the maximum limits on nitrites in food adopted in Directive 2006/52/EC.. The panel concluded that data provided by the Danish authorities did not provide a basis to revise the Acceptable Daily Intake (ADI) of 0.07mg/kg body weight/day for nitrite, acknowledging that exposure to preformed nitrosamines in food should be minimised by appropriate technological practices such as lowering the levels of nitrate and nitrite added to foods to the minimum required to achieve the necessary preservative effect and to ensure microbiological safety, in line with what had been concluded by Scientific Committee on Food in 1995 (EFSA, 2010).

4. MICROBIOLOGICAL ISSUES

4.1 Mode of action of nitrite

Nitrite in combination with salt is widely used in the production of cured meat products such as bacon and ham. One of the uses of nitrite in these products is to achieve safety with respect to food pathogens and in particular to inhibit growth of spore forming bacteria such as *Clostridium botulinum*.

The precise mode of action of nitrite is still not known and there are considered to be many possible target sites of action in the microbial cell. A good review of the biochemical basis for nitrite inhibition of *C. botulinum* in cured meats is given by Benedict (1980). The primary modes of action are reported to be (Singhal and Kulkarni, 2000; Surekha and Reddy, 2000):

(i) inhibition of respiration by inactivation of key enzymes

(ii) Reduction in the levels of intracellular ATP

(iii) reduction in the efficiency of the active transport systems by blocking important enzyme pathways

(iv) release of nitrous acid and nitric oxides

(v) formation of S-nitroso compounds by reaction of nitrite with haem proteins

Like many food preservatives, nitrite works better under acidic conditions, which favour the production of undissociated nitrous acid and thus permit its entry into the bacterial cell where it will have greater effect.

4.2 Nitrite loss

Nitrite levels in cured meats fall during storage and the level of residual nitrite is usually comparable in a range of products irrespective of in-going amount. There are many factors which will affect the level of residual nitrite in food products, including heat treatment, pH, presence of ascorbate and storage temperature. The rate of nitrite loss does not appear to have any clear relationship to the level of ingoing nitrite and cannot clearly be predicted from the in-going levels. Sofos *et al* (1980a) found that the residual level of nitrite fell to between 1 and 3ppm after 25 day's storage irrespective of whether 40, 80 or 120ppm was added to the original bacon product.

It is considered to be the residual amount of nitrite which is important with respect to *C.botulinum* control (EFSA 2003). However, there is some evidence to show that the starting levels are important too. Christiansen (1980) found that spores of *C. botulinum* germinated readily at in-going levels of 50 and 156 mg/kg nitrite once residual levels fell below 10mg/kg. However, it appears from their data that spores grew more rapidly at low residual amounts of nitrite when the in-going amount was lower. For example, when canned pork was formulated with 50mg/kg nitrite and stored at 27ºC, the residual levels of nitrite fell below 10mg/kg between day 7 and 12 and growth occurred by day 12. For canned pork formulated with 156mg/kg, the residual levels of nitrite fell below 10mg/kg on day 15 yet growth was not evident until day 43.

It would appear that the protein type affects the rate of depletion of nitrite and also the antibotulinal effect. Sofos *et al* (1979) found that 80mg/kg nitrite was less effective in chicken products than those made with beef or pork. They proposed that this might be due to higher levels of iron in the mechanically deboned meat which made the nitrite less effective. They concluded that a level of 80mg/kg nitrite was ineffective on its own and that higher levels were necessary. For example, they found that a level of 156mg/kg nitrite was significantly inhibitory against *C. botulinum*.

In summary, it would appear to be a combination of initial amount of nitrite present and the level of residual nitrite that is important with respect to inhibition of *C. botulinum*, although it should be noted that most studies quote the required inhibitory values as in-going amounts rather than residual amounts. There is no clear link between in-going and residual amounts that would allow a defined residual amount to be calculated for any given in-going amount. The residual levels of nitrite become depleted during storage to eventually reach the same level. However, it would appear that for any given residual level there is a greater anti-botulinal effect when the in-going amount is higher. Therefore, it is generally believed to be the residual nitrite which is important with respect to inhibition of *C.botulinum*, and it has previously been the practise to add levels of nitrite that are higher than the indicative in-going levels in order to achieve as high a residual level as possible within the maximum permitted values. However, this was no longer possible when the regulations changed to defined ingoing amounts of nitrite.

4.3 Guidelines

There have been a number of excellent reviews which document the historical research on the antimicrobial effects of nitrite (e.g. Tompkin, 2005; Benedict, 1980; Pierson and Smoot, 1982). There has also been some research on the effects of nitrites and nitrates on the safety of cured meats, particularly with regard to *C. botulinum*. However, much of the work was done in the 1950's through to the 1980's and concentrated on proteolytic strains of *C. botulinum* in canned meats. There has been little work carried out looking at the role of nitrite in ham and bacon products specifically. This lack of research with respect to chilled foods is the reason that nitrite was not included as a controlling factor to prevent the growth of psychrotrophic *C. botulinum* in MAP and VP chilled foods within current Guidance (ACMSF, 1992; FSA 2008; Betts and Betts, 2009).

In the early 1990's, ACMSF reviewed all the data available on the growth of psychrotrophic *C. botulinum* with a view to introducing a set of guidelines that, if followed correctly, would allow the safe production of chilled foods. These guidelines were published in 1992 (ACMSF, 1992) and they contain a list of intrinsic properties which, if at least one is met, will extend the shelf life of a chilled MAP / VP / low oxygen food to beyond 10 days. Since then Campden BRI has published a more industrially focussed document (Betts 1996 and Betts and Betts 2009), and the FSA has recently published an updated set of guidelines (FSA 2008). All these more recent documents adhere to the same set of control factors. Should none of the factors be met, the shelf life of a low oxygen packed, chilled food should be limited to ≤10 days at ≤8°C. The control factors mentioned in all the guidelines are as follows:

1. pH of 5 or less throughout the product
2. Water activity of 0.97 or less throughout the product
3. A salt level of 3.5% or more throughout the product
4. A heat treatment of 90°C for 10 minutes or equivalent
5. Any combination of preservative factors and / or heat which has been shown consistently to prevent growth and toxin production by psychrotrophic *C. botulinum.*

These guidelines have proven to be extremely successful at preventing outbreaks of botulism in the UK in chilled MAP/VP products and do not include the addition of nitrite. There was a full review of growth requirements data for *C.botulinum* produced for the FSA in 2006 (Peck *et a*l, 2007) and this concluded that the existing controls for the organism were adequate.

4.4 Effect of nitrite on food poisoning organisms

4.4.1 *C.botulinum*

Despite the lack of specific research on chilled cured products, general research on the antimicrobial effect of nitrite suggests that levels of 120 to 200 ppm (mg/kg) are considered sufficient to protect against *C. botulinum* growth and toxin production (Rhodehamel *et al,* 1992). Much of the work done on inhibition of *C. botulinum* by nitrite has concentrated on proteolyic strains. At a pH value of 6.0, the probability of toxin production was 54 % when the input level was 100mg/kg $NaNO_2$ but only 1% when the level was 300mg/kg (Roberts *et al*, 1981). The amount of in-going nitrite needed to inhibit *C. botulinum* varies considerably depending on the pH of the product, the heat treatment it receives, the presence of ascorbate and the number of spores present. Research also suggests that the levels required to achieve food safety seem to be well established and the addition of nitrite to cured meats has resulted in a good historical safety record for these types of foods, (Pierson and Smoot, 1982).

The influence of pH, nitrite and sorbic acid on growth of proteolytic *C. botulinum* in a chicken emulsion at an abuse storage temperature of 27ºC was evaluated by Sofos *et al* (1980b). In the control samples, toxin was formed within 4 days. The presence of 40mg/kg added nitrite did not cause any delay in toxin production whereas, the addition of 156mg/kg nitrite doubled the time to toxin production to 8 days. The authors considered that this effect was due to a higher residual amount of nitrite in the product when a higher in-going amount was used in the formulation.

The literature has shown that nitrite acts synergistically with salt to inhibit *C. botulinum*. The amount required to achieve inhibition varies between different foods but in products with a low salt content and prolonged shelf life, addition of between 50 and 150 mg/kg is necessary (EFSA, 2003).

4.4.2 *C.perfringens*

Gibson and Roberts (1986a) looked at the combined effects of salt and nitrite on *Clostridium perfringens* at different temperatures and pH values. At storage temperatures of 20 to 35ºC, they found that growth of this organism was prevented by the levels of curing salts used commercially (up to 200mg/kg) provided the pH was 6.2 or below. This was usually accompanied by a salt level of 3%. At temperatures below 20ºC, this organism grew slowly without the addition of nitrite or salt.

4.4. *L.monocytogenes*

Nitrite has been shown to inhibit *Listeria monocytogenes* in conditions found in cured meat products (Buchanan *et al*, 1989). The inhibitory effects were temperature and pH dependent. For example, the time for a 4-log increase in numbers of *L. monocytogenes* was 8 hours at 37ºC and 287 hours at 5ºC when the salt level was 0.5%, the nitrite was 100mg/kg and the pH was 6.0. When the salt level was increased to 4.5%, the times for a 4-log increase were 11 and 479 hours for 37ºC and 5ºC respectively. Whiting and Masana (1994) also assessed the effect of nitrite on *L.monocytogenes* growth and found that the addition of 150 or 300ppm to a simulated meat product produced at a range of pH values (4.0-5.1) decreased the time for a 4 log reduction compared with 0ppm, presumably by increasing the rate of death of the organism.

Further studies (McClure *et al*, 1991) showed that at 20ºC and below no growth of *L. monocytogenes* was detected within 21 days at nitrite concentrations of 50mg/kg when the pH was 5.3 or below. When the pH was at pH 6.0 and above, nitrite had little effect even at 400mg/kg and temperatures down to 10ºC.

Slices of cured meat were inoculated with *L.monocytogenes* and stored at 0 or 5°C by Duffy *et al* (1994). They found that the time for a 3 log increase was twice as long for meat containing 70-140ppm nitrite than 0ppm.

Buncic et al (1995) found that 125ppm nitrite had a bacteriostatic effect on *Listeria* in broth at pH 5.5 and 4°C. In combination with 0.3% potassium sorbate a listericidal effect was noted.

Birzele *et al* (2005) found that *L.monocytogenes* growth was inhibited in spreadable ham and onion sausages containing 53ppm nitrite when stored at 8°C for 15 days.

Nyachuba et al (2007) found that when *L. monocytogenes* was exposed to 100 or 200ppm nitrite there was 83 to 95% injury observed. However, this varied from strain to strain.

4.4.4 *Salmonella*

With respect to *Salmonella* at 10°C - 35°C, growth was not prevented by most combinations of salt (1 – 6% w/v), pH (5.6, 6.2 and 6.8) and sodium nitrite (0-400 ppm) tested. Inhibition only occurred under extreme conditions of pH (5.6), temperature (10°C) and nitrite (400ppm) (Gibson and Roberts 1986b).

Rice and Pierson (1982) found that growth of *Salmonella* was inhibited in frankfurters containing 156ppm nitrite when they were stored at 15°C but not at 27°C. A level of 50ppm nitrite did not prevent growth at either temperature.

A level of 53ppm nitrite was shown to not be inhibitory to the growth of *S.* Enteritidis in spreadable ham and onion sausages containing 53ppm nitrite when stored at 8°C for 15 days (Birzele *et al* 2005).

4.4.5 *E.coli*

Buchanan and Bagi (1994) found that the antimicrobial action of sodium nitrite on *E.coli* O157 was strongly pH dependent and inhibition of growth was significant at pH values <5.5 and at low temperatures. They found that at pH 5.5 and 28°C there was an extension of lag time and decrease in growth rate at 200ppm nitrite. At pH 4.5 a level of 200ppm nitrite was bactericidal.

It was found by Birzele *et al* (2005) that a low level of nitrite did not inhibit the growth of *E.coli.* They found that growth of *E.coli* was not inhibited in spreadable ham and onion sausages containing 53ppm nitrite when stored at 8°C for 15 days.

4.4.6 *S.aureus*

With regards to *Staphylococcus aureus* the bacteriostatic effect of nitrite was dependent on pH and oxygen availability. However, this organism is highly tolerant to increased salt levels and at the levels present in cured meat products, growth of *S. aureus* occurred at up to 200mg/kg nitrite, albeit slowly at refrigeration temperatures (Buchanan *et al*, 1993). Smith and Palumbo (1980) also found that *S.aureus* growth was inhibited by nitrite. They found that 100ppm of nitrite inhibited *S.aureus* growth in a model sausage system (35°C for 3 days) under anaerobic conditions but a level of 150ppm nitrite was required to inhibit growth under aerobic conditions.

It was shown by Birzele *et al* (2005) that a low level of nitrite did not inhibit the growth of *S.aureus.* They found that growth of *S.aureus* was not inhibited in spreadable ham and onion sausages containing 53ppm nitrite when stored at 8°C for 15 days. Bang *et al* (2008) found that addition of 154ppm of nitrite to pork sausage prior to drying (10 days at 21°C) was not sufficient to prevent the growth of *S.aureus*.

4.4.7 *B.cereus*

The growth of *Bacillus cereus* was also found to be affected by combinations of pH, salt and nitrite (Benedict *et al* 1993). For example at 12ºC, pH 6.75 and 50mg/kg nitrite, the lag time was 136 hours with 3.5% salt and 81 hours with 1.5% added salt. Under adverse conditions of temperature or pH, the addition of salt or nitrite completely inhibited growth of *B. cereus*.

4.4.8 *Shigella*

Under adverse conditions of temperature or pH, the addition of salt or nitrite was sufficient to prevent growth of *Shigella flexneri* (Zaika *et al* 1994). At 15ºC, pH7.0, 2.5% salt, there was a lag time of 274 hours without nitrite and no growth at all with 200mg/kg nitrite. At 19ºC, pH6.5 and 0.5% salt growth occurred rapidly for 50,100 and 200 mg/kg and growth was only inhibited in the presence of 1000 mg/kg nitrite. However, when the salt was increased to 2.5% growth only occurred with 50mg/kg nitrite but was inhibited at levels of 100mg/kg or higher.

4.4 9 *Yersinia*

Yersinia enterocolitica was not inhibited by up to 200mg/kg nitrite at low temperatures although when the pH was low, and salt was included, the growth rate was slowed with the addition of nitrite. At 5°C and pH 5.5 the lag time was 79 hours with 0.5% salt but was 242 hours with 2%salt and 50mg/kg nitrite. (Bhaduri *et al*, 1994).

4.4.10 Spoilage organisms

The effect of nitrite on meat spoilage organisms has not been so extensively studied. It would appear that nitrite has limited effect against yeasts (Nielson, 1983a) and many of the microbial groups associated with spoilage of meat products such as *Pseudomonas* and *Lactobacillus* at the levels permitted in cured meat products (Singhal and Kulkarni, 2000). Some spoilage organisms are more sensitive, for example, Enterobacteriaceae, *Brochothrix thermosphacta,* and *Moraxella* spp. were inhibited by up to 200ppm sodium nitrite in Bologna-type sausages (Nielson 1983a,b). Bang et al (2008) found that addition of 154ppm of nitrite to pork sausage limited coliform growth during the drying step of 10 days at 21°C. Birzele *et al* (2005) found that Enterobacteriaceae growth was inhibited in spreadable ham and onion sausages containing 53ppm nitrite when stored at 8°C. However, growth of lactic acid bacteria was not inhibited. Sameshima *et al*. (1998) have shown that the growth rate of *Lactobacillus viridescens* and *Enterococcus faecalis* was up to three times slower in vacuum packaged pork sausage containing 200ppm sodium nitrite and stored at 10°C compared to controls containing no nitrite.

4.5 Effect of removal of nitrite and reduction of salt

There is a move to remove nitrite from organically produced ham and bacon products and in addition to this the Food Standards Agency (FSA, 2009) has an initiative to lower the levels of salt in cured meat products. The salt reduction targets published by the FSA are given in Table 1. These changes have been suggested because of the effects on health from consuming too much salt or from the potential presence of carcinogenic compounds from nitrite. However, these changes have the potential to decrease the microbial safety of cured meat products and limit shelf life, if no additional preservatives are used in the product formulation or the shelf-life is not adjusted.

Table 1: FSA salt reduction targets

Main Product Category	Current 2010 Targets (g salt or mg sodium per 100g)*	Revised 2010 Targets (g salt or mg sodium per 100g)*	Targets for 2012 g salt or mg sodium per 100g)*
1.1 Bacon Includes all types of injection cured bacon, e.g. sliced back, streaky, smoked and unsmoked bacon, bacon joints etc. Excludes all dry and immersion cured bacon.	3.5g salt or 1400mg sodium (average)	3.13g salt or 1250mg sodium (average)	2.88g salt or 1150mg sodium (average)
1.2 Ham/other cured meats Includes hams, cured pork loin and shoulder etc. Excludes 'Protected Designation of Origin' and traditional speciality guaranteed products, e.g. Parma ham. Also excludes speciality products produced using traditional methods such as immersion and dry cured processes	2.5g salt or 1000mg sodium (average)	2.0g salt or 800mg sodium (average)	1.63g salt or 650mg sodium (average)

As the literature has suggested nitrite alone, or in particular in combination with salt, has an effect on the microbial safety and spoilage of cured meat products. However, not only does the safety of cured meat products rely upon presence of appropriate levels of salt and nitrite, it also relies on pH and temperature control, as often none of these preservation factors is sufficient on its own to achieve inhibition of microorganisms. Any changes to levels of these factors must be considered carefully with respect to the microbial safety of the products.

Therefore, the removal of nitrite may increase the risk of growth of any food pathogens present, particularly when another factor such as the salt level is also being reduced. Any change to either salt level or nitrite level alone would have the potential to increase the risks of growth of food poisoning organisms and also food spoilage organisms. A simultaneous reduction in both these factors could have serious food safety implications if it allowed growth of pathogenic organisms.

4.5.1 Predictive modelling

A way of assessing the potential effect of the removal of nitrite in combination with a reduction in salt level is predictive microbiological modelling.

Predictive models have been developed extensively over the past few years and are useful tools for assessing the effect of environmental conditions on growth of pathogens and spoilage organisms.

Predictive microbiological models are developed from laboratory data obtained under a defined set of experimental conditions to predict the likely responses under new combinations of those conditions not previously tested. For example, data describing the effect of temperature on an organism at 5, 10 and 15°C can be used to predict the likely growth at 8°C. The same principle applies to any test parameter such as salt, pH or preservatives. The power of this tool for new product development is very apparent. Modifications of new or existing recipes can be tried on the computer before embarking on expensive laboratory experiments or pilot scale production runs.

There are currently a number of publicly available modelling systems that can be accessed by the food industry. For food pathogens there is Combase Predictor (which is based on the data which was formerly available as FoodMicromodel™) available at: http://ifrsvwwwdev.ifrn.bbsrc.ac.uk/CombasePMP/GP/ComBase_Predictor.aspx and the USDA Pathogen Modelling Program (PMP). For spoilage organisms there is the Campden BRI *FORECAST* Service.

Because nitrite and salt interact with each other and with other environmental factors such as pH and storage temperature, it is not easy to define critical combinations of these factors once you move away from the generally accepted levels of these factors required to prevent growth, e.g. 150mg/kg nitrite and 3.5% salt for psychrotrophic *C. botulinum*.

Predictive models can be used to assess the likely change in microbial growth characteristics caused by changing the product formulation. Not all of the predictive models allow the input of nitrite at the relevant levels or allow the input of low temperatures. Three of these predictive models have been used to assess the effect nitrite and salt levels have on the potential for growth of two key pathogens, *Salmonella* and *Listeria,* and general meat spoilage. The temperature used for the modelling was 8^{o}C, a pH value of 6.0 was chosen to represent ham and bacon, the FSA targets were used as the salt (%) input levels and a range of nitrite levels (ppm) from 0-200 were used. The initial levels for the pathogens was 10 cfu/g and 100 cfu/g for the meat spoilage models.

The times for a 0.5 log increase (equivalent to lag time) are given in Tables 2 and 3 for *Salmonella* and *Listeria* respectively. The time for a 4 log increase from 2.0 log cfu/g (100 cfu/g) to 6 log cfu/g (1000000 cfu/g) of meat spoilage organisms is given in Table 4. The corresponding growth curves are given in Figures 1-18.

4.5.1.1 Salmonella

As can be seen in Table 3 the time taken for a 0.5 log increase in *Salmonella* ranged from 4 to 30d depending upon salt level and nitrite level. The predictions indicate that a decrease in nitrite level affects the time for a 0.5 log increase more than a decrease in salt level. The predicted time for a 0.5 log increase ranged from 8.5d at 50ppm nitrite at the current salt level for bacon (3.5% salt) compared with 5.5d at 0ppm. With regards to ham, at the current salt level (2.5% salt) and at a nitrite level of 50ppm, the predicted time for a 0.5 log increase is 6.9d compared with 4.5d at 0ppm.

Table2: Time (days) for a 0.5 log increase of *Salmonella*

Time (d) for 0.5 log increase of *Salmonella*						
	Bacon			Ham		
	2010	Revised 2010	2012	2010	Revised 2010	2012
	Salt %					
nitrite (ppm)	3.5	3.13	2.88	2.5	2	1.63
200	30.7	28.7	26.8	24.9	23.0	21.7
175	25.0	22.8	22.0	20.3	18.5	17.5
150	20.0	18.3	17.5	16.3	15.0	14.0
125	16.3	15.0	14.3	13.3	12.0	11.4
100	13.1	12.0	11.5	10.5	9.6	9.2
75	10.5	9.6	9.2	8.6	7.8	7.3
50	**8.5**	**7.7**	**7.5**	**6.9**	**6.3**	**5.9**
25	6.8	6.3	6.0	5.6	5.1	4.8
0	**5.5**	**5.1**	**4.8**	**4.5**	**4.1**	**3.8**

Figures in bold type indicate current and proposed legally permitted nitrite levels for bacon and ham

4.5.1.2 Listeria

As can be seen in Table 3 the time taken for a 0.5 log increase in *Listeria* ranged from 2.8 to 7.2d depending upon salt level and nitrite level. This suggests that *Listeria* is more tolerant to nitrite and salt than *Salmonella*. The predictions indicate that a decrease in nitrite level affects the time for a 0.5 log increase more than a decrease in salt level. The predicted time for a 0.5 log increase ranged from 3.9d at 50ppm nitrite at the current salt level for bacon (3.5% salt) compared with 3.3d at 0ppm. With regards to ham at the current salt level (2.5% salt) at a nitrite level of 50ppm the predicted time for a 0.5 log increase is 3.5d compared with 2.9d at 0ppm.

Table 3: Time (days) for a 0.5 log increase of *L.monocytogenes*

Time (d) for 0.5 log increase of *L.monocytogenes*						
	Bacon			Ham		
	Salt (%)					
	2010	Revised 2010	2012	2010	Revised 2010	2012
nitrite (ppm)	3.5	3.13	2.88	2.5	2	1.63
200	7.2	7.0	6.8	6.5	6.3	6.2
175	6.5	6.2	6.0	5.8	5.6	5.5
150	5.8	5.6	5.5	5.3	5.1	5.0
125	5.2	5.0	4.9	4.7	4.6	4.5
100	4.8	4.6	4.4	4.3	4.1	4.0
75	4.3	4.1	4.0	3.8	3.8	3.7
50	**3.9**	**3.8**	**3.7**	**3.5**	**3.4**	**3.3**
25	3.6	3.4	3.3	3.2	3.1	3.0
0	**3.3**	**3.1**	**3.0**	**2.9**	**2.8**	**2.8**

Figures in bold type indicate current and proposed legally permitted nitrite levels for bacon and ham

4.5.1.3 Meat spoilage organisms

As can be seen in Table 4 salt does not have much of an effect on the time for a 4 log increase of meat spoilage organisms. The effect of nitrite is also not as great as for *Salmonella* or *Listeria.* However, there is about a 0.5 day difference in time for a 4 log increase for both bacon and ham when nitrite is 50ppm compared with 0ppm.

Table 4: Time (days) for a 4 log increase from 2.0 log cfu/g to 6 log cfu/g of meat spoilage organisms

	Bacon			Ham		
	2010	Revised 2010	2012	2010	Revised 2010	2012
	Salt %					
nitrite (ppm)	3.5	3.13	2.88	2.5	2	1.63
200	11.0	9.9	9.3	8.5	7.6	7.0
175	10.9	9.9	9.3	8.5	7.6	7.0
150	10.8	9.7	9.2	8.3	7.5	6.9
125	10.5	9.5	8.9	8.2	7.3	6.7
100	10.3	9.3	8.7	7.9	7.1	6.5
75	10.0	9.0	8.4	7.7	6.8	6.3
50	**9.6**	**8.6**	**8.0**	**7.3**	**6.5**	**6.0**
25	9.2	8.2	7.7	7.0	6.2	5.7
0	**8.8**	**7.8**	**7.3**	**6.6**	**5.8**	**5.4**

Figures in bold type indicate current and proposed legally permitted nitrite levels for bacon and ham

4.5.2 Growth curves for Salmonella, Listeria and meat spoilage organisms

4.5.2.1 Bacon 2010 salt target

Figure 1 Salmonella

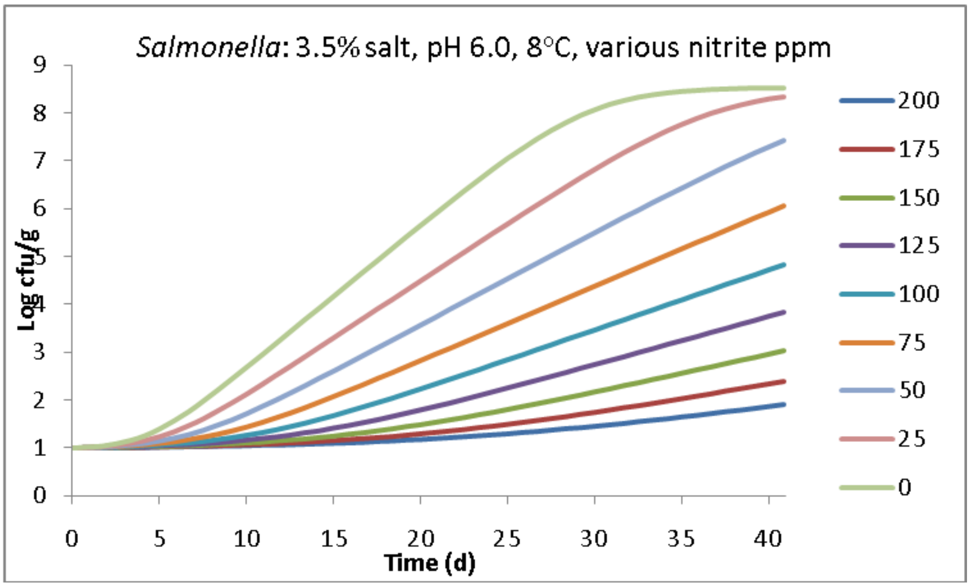


Figure 2: Listeria

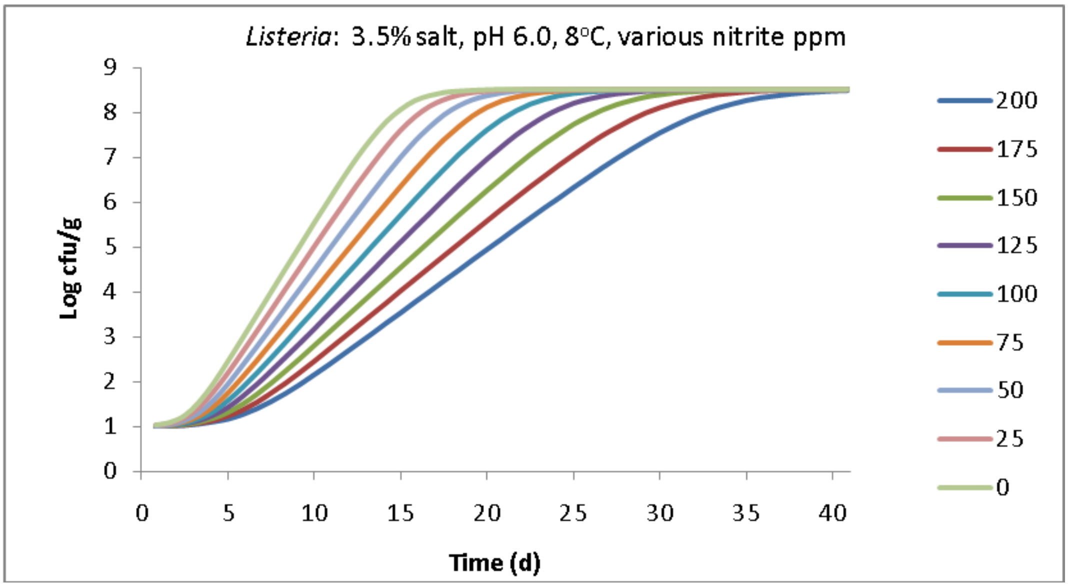
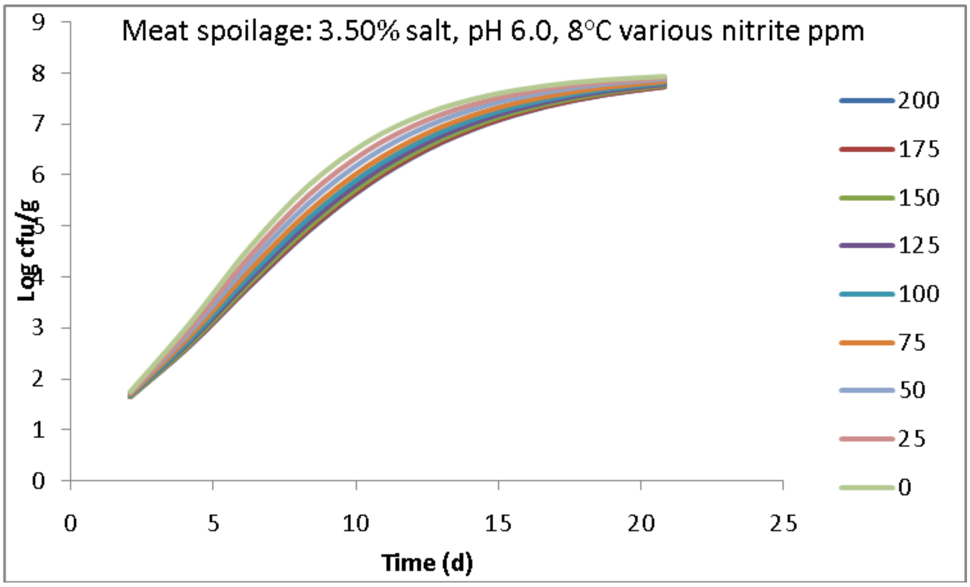


Figure 3:Meat spoilage organisms



4.5.2.2 Bacon revised salt target 2010

Figure 4: Salmonella

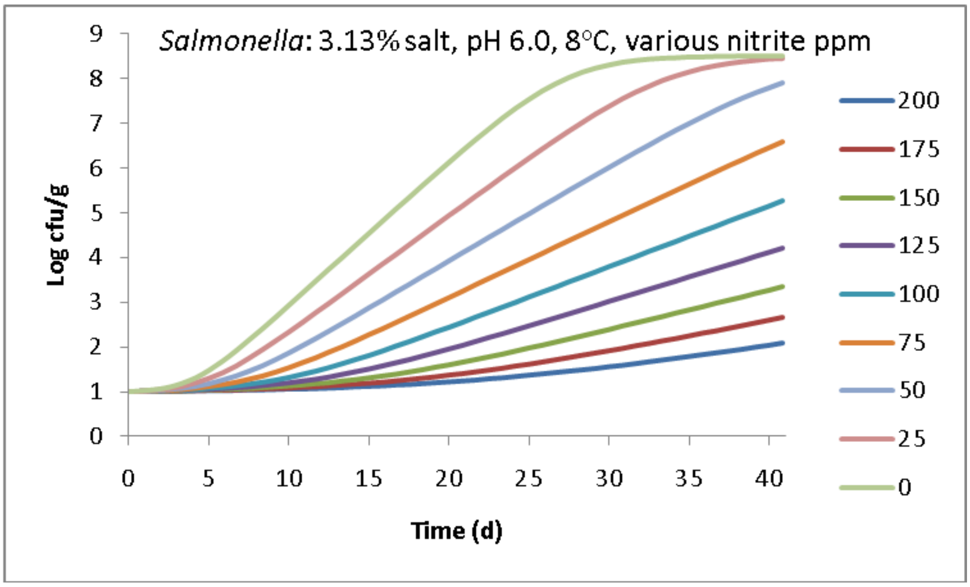


Figure 5: Listeria

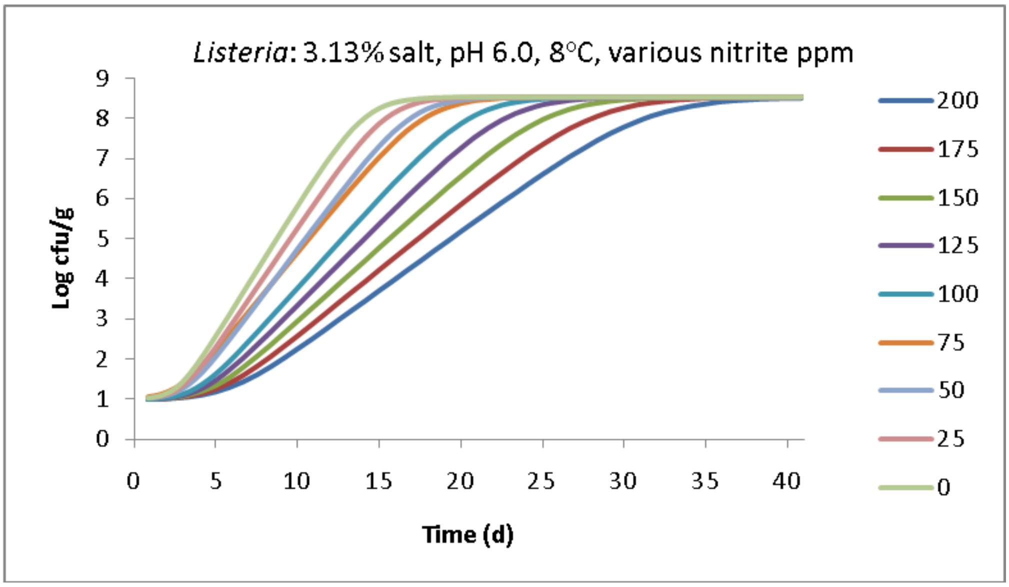
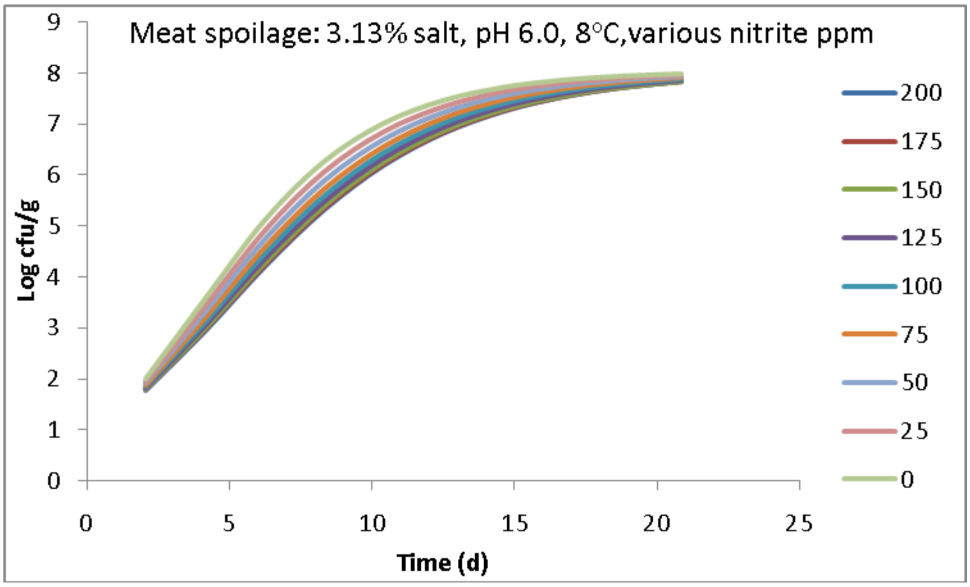


Figure 6: Meat spoilage organisms



4.5.2.3 Bacon 2012 salt target

Figure 7: Salmonella

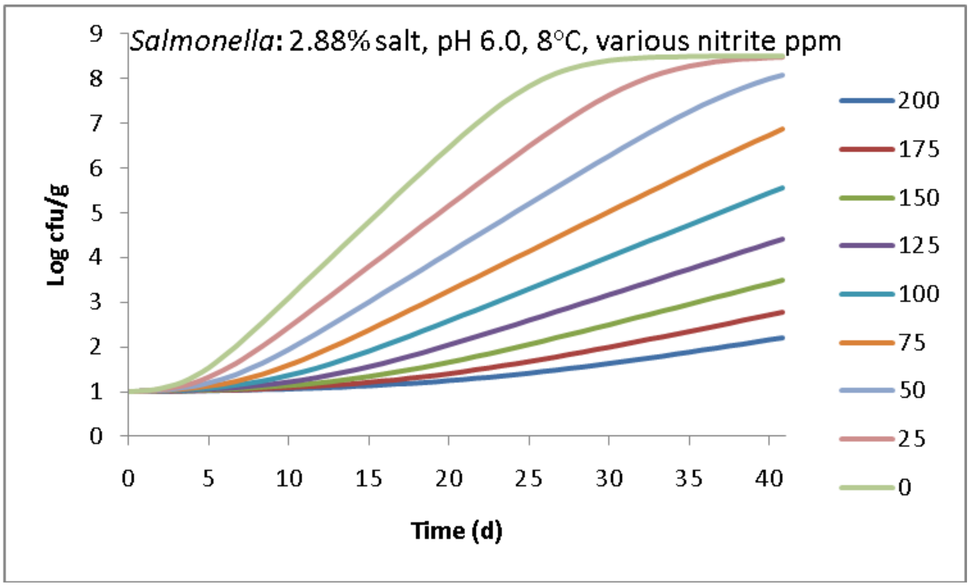


Figure 8: Listeria

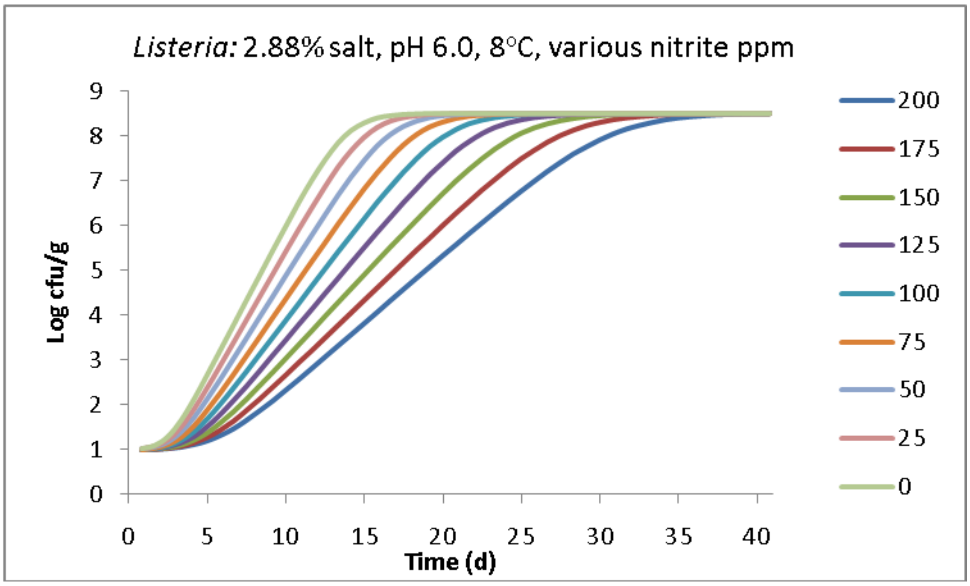
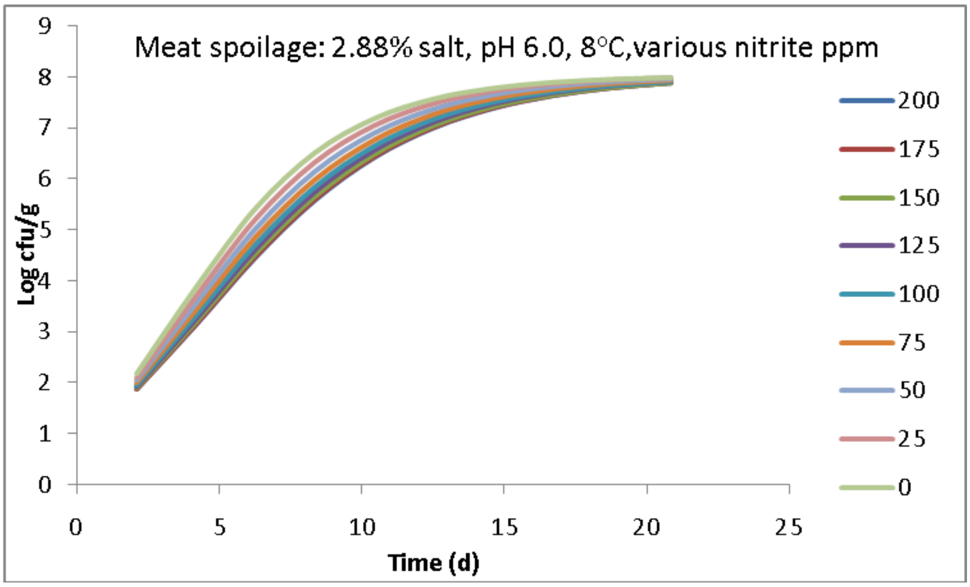


Figure 9:Meat spoilage organisms



4.5.2.4 Ham 2010 salt target target

Figure 10: Salmonella

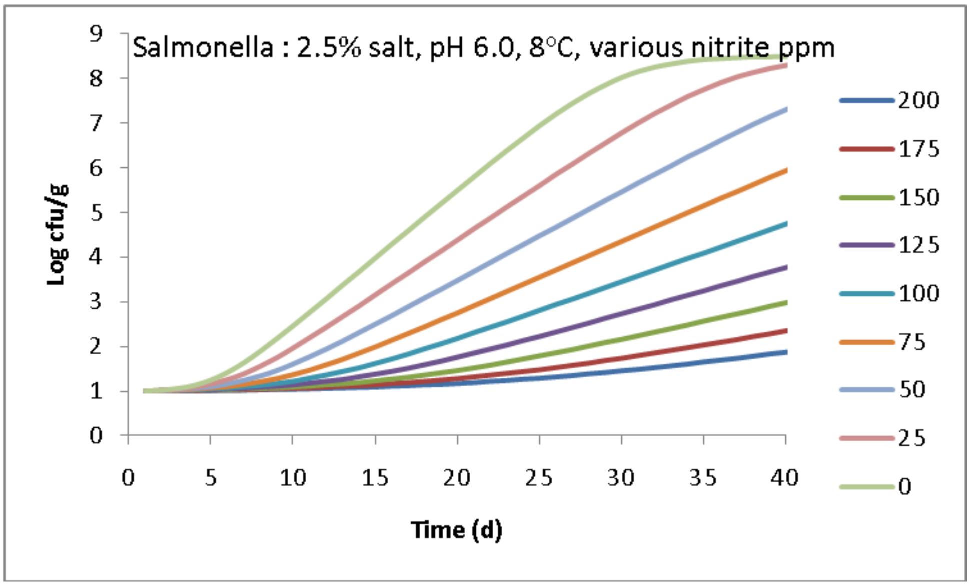


Figure 11: Listeria

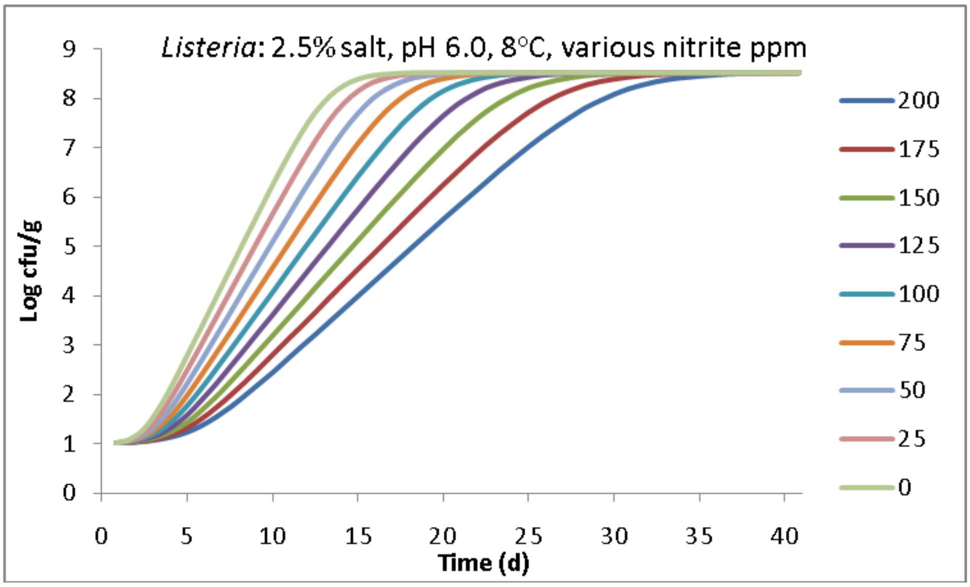
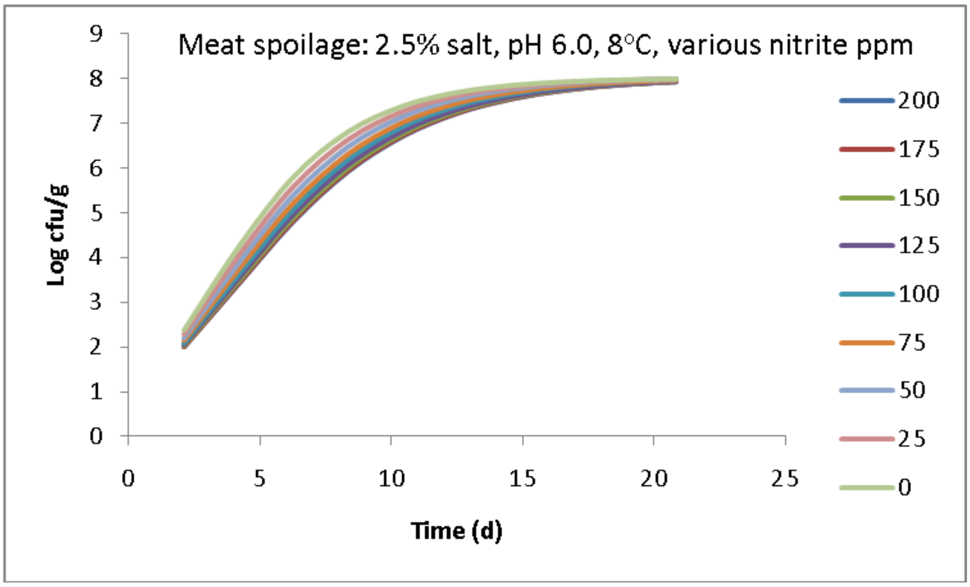


Figure 12: Meat spoilage organisms



4.5.2.5 Ham revised 2010 salt target

Figure 13 Salmonella

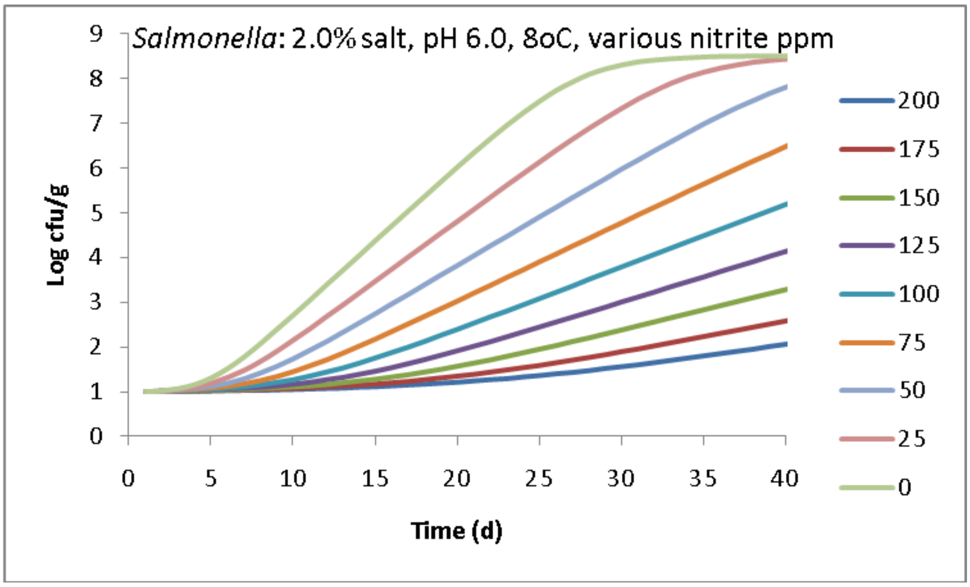


Figure 14: Listeria

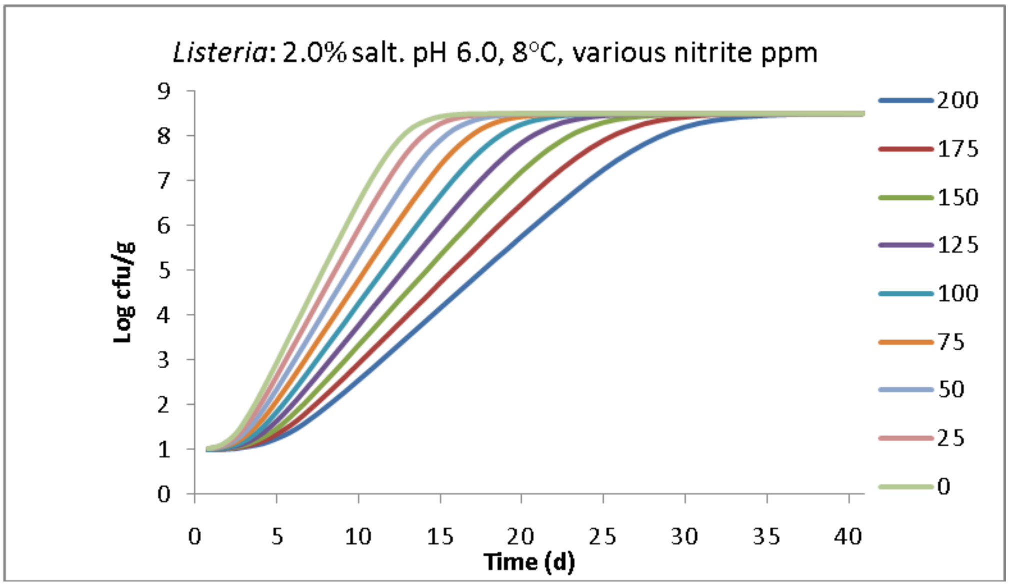
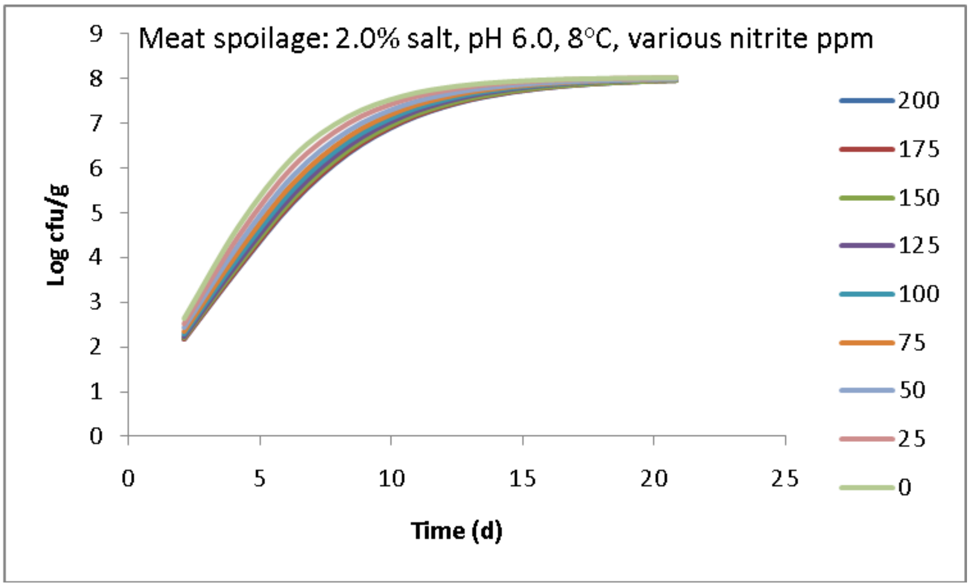


Figure 15: Meat spoilage organisms



4.5.2.6 Ham 2012 salt target

Figure 16: Salmonella

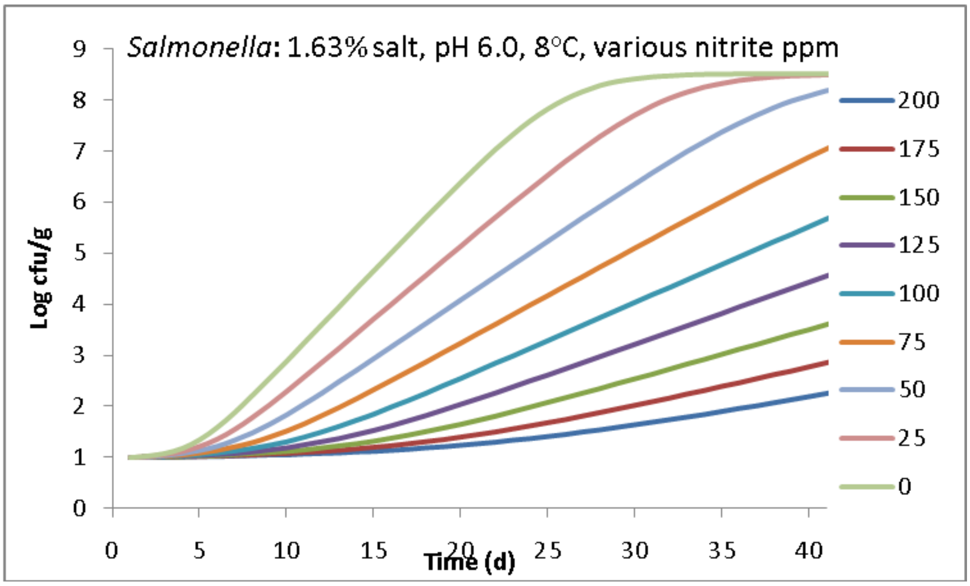


Figure 17: Listeria

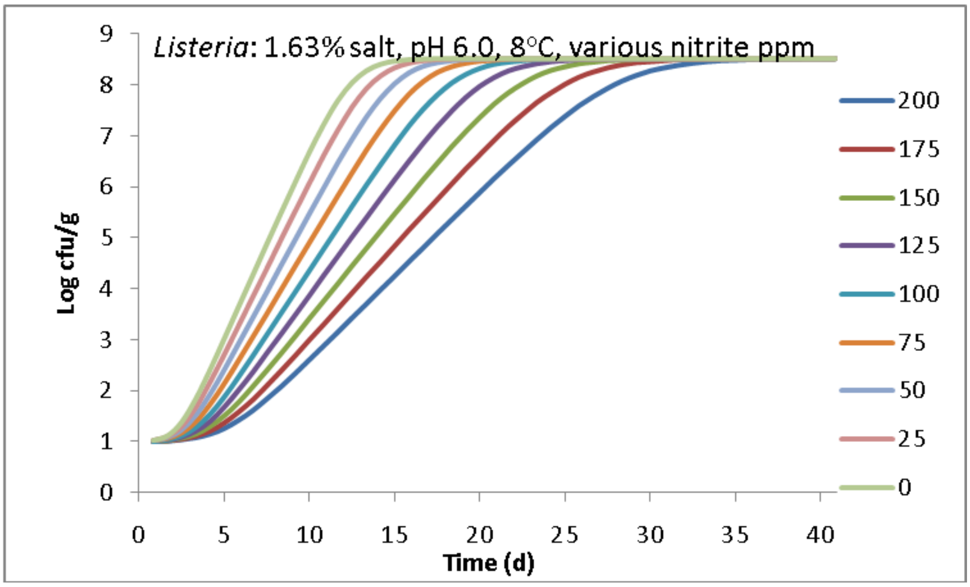
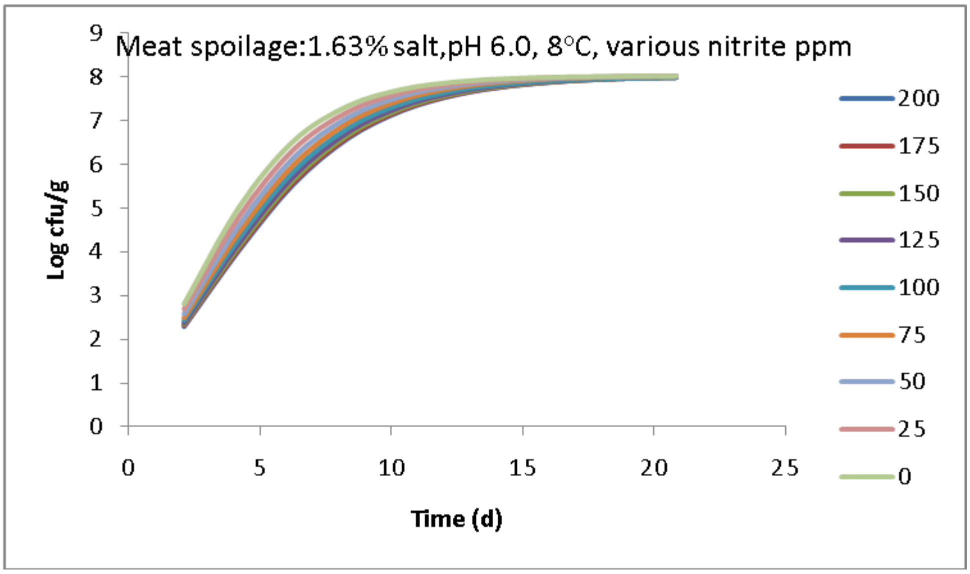


Figure 18: Meat spoilage organisms



4.6 Alternatives to nitrite from a microbiological perspective

4.6.1 Sorbate

Sorbate tends to be used as an anti-fungal agent but some work has been carried out to assess the efficacy of sorbate against organisms such as *C.botulinum*.

Numerous authors including Sofos *et al* (1979) and Tompkin *et al* (1974) have shown sorbate to be effective in inhibiting sporulation of *C.botulinum,* providing the pH is low enough, and sorbate is present in a high enough concentration. However, work by Sofos *et al* (1979) with a frankfurter emulsion system found that spore germination was slower in samples containing 0.2% sorbic acid compared to those containing nitrite only or no preservatives.

The influence of pH, nitrite and sorbic acid on the growth of proteolytic *C. botulinum* in a chicken emulsion at a storage temperature of 27ºC was evaluated by Sofos *et al* (1980b). In control samples containing no preservatives, toxin was formed within 4 days. The addition of 156ppm nitrite doubled the time to toxin production to 8 days. Sorbic acid acted synergistically with the nitrite to prevent toxin formation. The effect of 40mg/kg nitrite and 2000ppm sorbic acid was greater than the acid alone or the use of 156mg/kg nitrite. The authors concluded that as well as the antimicrobial effects of the acid itself, it also acted to reduce the rate of nitrite depletion in the meat products.

Jones and Betts (2009) demonstrated that at 2000ppm potassium sorbate had an inhibitory action on non-proteolytic *C.botulinum* in broth studies where 2% salt was present, the pH was 5.5 and the broths were stored at 30°C.

The anti-botulinal mode of action of sorbic acid and sorbates is unclear. However, a few authors including Blocher and Busta (1985), Lund *et al* (1987), Seward *et al* (1982) and Smoot and Pierson (1981) suggest that the undissociated form of the acid has the greatest effect. Smoot and Pierson (1981) also suggest that sorbate inhibits the binding of amino acids such as L-alanine and L-cysteine to sites on the *C. botulinum* spore which trigger germination. The authors noted that this effect is reversible, i.e. spores which had been inhibited by sorbate were able to germinate once sorbate had been removed from the system.

Sorbates also have the beneficial effect of retaining some of their antimicrobial activity (possibly due to the dissociated form) as the pH rises, albeit this is much weaker than the undissociated form.

Sorbate has been shown to have an antimicrobial action on other microorganisms. Rice and Pierson (1982) found that sorbate at a level of 2600 or 3900ppm was effective in preventing *Salmonella* growth in frankfurters either alone or in combination with 50 or 156ppm nitrite when stored at 15 or 27°C for up to 21 days. Smith and Palumbo (1980) found that *S.aureus* growth was inhibited by sorbate. They found that 2500ppm of sorbate inhibited *S.aureus* growth in a model sausage system (35°C for 3 days) under anaerobic conditions but a level of 5000ppm sorbate was required to inhibit growth under aerobic conditions. The effect on *Listeria* has also been studied. Buncic et al (1995) found that 0.3% potassium sorbate had a bacteriostatic effect on *Listeria* in broth at pH 5.5 and 4°C.

4.6.2 Benzoate

Benzoic acid and its salts are primarily used to inhibit the growth of moulds and yeasts in low pH products such as fruit and vegetable preserves and pickles. The use of benzoates as antibacterial compounds has received little attention compared to other weak acid preservatives such as sorbates and lactates. A solution containing benzoate at a concentration of 25% w/v has been shown to inhibit *Listeria monocytogenes* growth on the surface of frankfurters (Islam et al 2002a) and sliced meats (Islam *et al* 2002b), and a 0.1% solution has been shown to inhibit the growth of *Eschericia coli* in apple juice (Zhao *et al* 1993). There is little evidence showing benzoate based inhibition of *C. botulinum*. However, Jones and Betts (2009) demonstrated that at 2000ppm sodium benzoate had an inhibitory action on non-proteolytic *C.botulinum* in broth studies where no salt was present, the pH was 7.0 and the broths were stored at 8°C.

4.6.3 Lactate

Lactates tend to be added to foods for their taste, buffering ability and humectant properties (Luck and Jaeger 1997 and Davidson *et al* 2005). Lactates also have a preservative action, and the literature indicates that *C. botulinum* is inhibited by lactic acid and its salts. Notermans and Defrenne (1981) noted a reduction in toxin formation by proteolytic *C. botulinum* in a meat slurry as pH was lowered to below 5.2 using lactic acid. Maas *et al* (1989) found that a lactate salt (sodium lactate) was effective in inhibiting *C. botulinum* toxin formation in a broth based system and in a ‘Cook in Bag’ turkey product.

Meng and Genigeorgis (1993) developed a set of equations to model the extension of lag time for psychrotrophic *C. botulinum* in the presence of varying concentrations of sodium lactate and sodium chloride. This model was based on results observed in cooked turkey meat, which followed the expected pattern of increased concentrations of lactate or sodium chloride increasing the lag phase.

Houtsma *et al* (1994) showed that lactate mediated inhibition of proteolytic *C. botulinum* toxin formation was more effective at lower temperatures, and that the effect was not due to lowering the water activity of the broth system used. This work also demonstrated an additive effect for sodium lactate and sodium chloride. Meyer *et al* (2003) noted that a psychrotrophic, non-proteolytic *Clostridium* isolate was inhibited by either sodium lactate at a concentration of 2.5%, or a combination of 1.25% sodium lactate and 0.25% sodium diacetate in a cook-in-bag turkey product.

Jones and Betts (2009) demonstrated that addition of 2% potassium lactate had an inhibitory action on non-proteolytic *C.botulinum* in broth studies where 2% salt was present, the pH was 5.5 and the broths were stored at 30°C.

The effect on *Listeria* has also been studied. Buncic et al (1995) found that 4% sodium lactate had a bacteriostatic effect on *Listeria* in broth at pH 5.5 and 4°C.

4.6.4 Lactic acid bacteria

Tanaka *et al* (1980) investigated the effect of acid formation on the inhibition of *botulinum* toxin formation in bacon. Product was formulated with 1.55% salt and 120ppm sodium nitrite and stored at 27ºC. This level of nitrite was not sufficient to inhibit toxin formation, which occurred after 1 week. However, when lactic acid bacteria were added with a fermentable carbohydrate source, they were able to produce acid from the sugar and thus lower the pH of the product. This in combination with the added nitrite was more effective than nitrite alone.

Further work by Tanaka *et al* (1985) also found that the Wisconsin process (addition of lactic acid bacteria and fermentable carbohydrate) for bacon with 40 or 80ppm nitrite was more effective than the use of 120pm nitrite alone.

Whilst the use of natural antimicrobials such as lactic acid or bacteriocins may prevent growth of some food pathogens, the addition of salt and nitrite may in fact decrease the effectiveness. Hornbaek *et al* (2004) showed that *Leuconostoc carnosum* had good antilisterial activities but that these were reduced in the presence of salt (2.5%) or nitrite (60mg/kg)

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4.7 Conclusions

Cured meats such as ham and bacon are examples of products which are, and have always historically been, preserved by hurdle technology where a careful balance of temperature, pH, salt and nitrite is used to achieve product stability. From the various data reviewed it would appear that nitrite can be inhibitory to a range of pathogens at in-going levels of 50mg/kg to 200mg/kg when used in combination with low storage temperature, reduced pH (i.e.<6.0) and increased salt levels (up to 3%). Any change to a single one of these factors will disturb the balance of the preservation system. Simultaneous changes in two of these factors could have serious consequences with respect to food safety. At the very least it will have major commercial implications as the shelf-life of every product may need to be re-evaluated either by practical studies or by a review of the HACCP plan.

In order to maintain safety and shelf-life, the formulation of cured meat products may need to be altered to include additional preservative measures such as sorbate or lactate. If no changes to product formulation are desired then a reduction in shelf-life may be necessary to maintain product safety. The literature suggests that sorbate, benzoate or lactate could be potential alternatives to nitrite with respect to antimicrobial action. However published work reporting uses of these preservatives is very limited and more research would be required to establish this fully. In addition the use of these alternatives would need to be considered in light of current legislation to establish whether they could legally be used in such products at effective concentrations.

Predictive modelling has shown that reducing the level of nitrite may have an effect on the growth rate of *Salmonella* and *Listeria* and the removal of nitrite may also have an impact on the growth of meat spoilage organisms. The predictions have therefore demonstrated that the removal of nitrite may affect the safety and spoilage of ham and bacon and therefore impact on shelf life.

To summarise the findings of this review:

1 The level of nitrite in cured meats eventually depletes to the same residual level irrespective of in-going amount, although many factors will affect the rate of depletion.

2 Residual level of nitrite has been reported to be the important factor in control of *C. botulinum*, however, in-going level influences the rate of nitrite depletion and thus is also important with respect to control of this organisms and at any given residual level there appears to be more antimicrobial effect when there was a higher in-going level of nitrite.

3 It has been demonstrated that the inhibitory combinations of salt and nitrite differ for each pathogen and are affected by environmental conditions such as pH and temperature. It is difficult to give blanket recommendations on critical levels of combinations of these factors.

4 Decreasing the levels of salt and / or nitrite will generally make the product more favourable to microbial growth.

5. ALTERNATIVES TO NITRITE

Various possibilities to eliminate the use of nitrites and thus reduce possible hazards from nitrosamines were investigated in the 1970’s. Alternative preservatives along with natural and artificial food colours were investigated and attempts were also made to produce nitrite-free bacon using nitric oxide. (British Patent No. 1375700, Ranken, 2000) There are ingredients that can mimic some of the effects of nitrite with varying degrees of success, suggesting that an alternative curing mixture could be developed (Pegg and Shahidi, 2000). This mixture would be required to contain a colour, an antioxidant and an antimicrobial agent (Wettasinghe and Shahidi, 1997).

Sebranek and Bacus (2007) discuss a study conducted by Iowa State University in 2006 reviewing commercially available uncured products, which demonstrated typical cured meat colour and appearance. This study revealed that the products contained the following

- sea salt
- evaporated cane juice, raw sugar or tubinado sugar
- lactic acid starter culture
- natural spices or flavourings
- celery juice or celery concentrate

Table 5, which follows, summarises a literature review of studies carried out using nitrite replacers. The sections that follow Table 5 provide further information on each system listed in the table.

Table 5 A summary of studies carried out using nitrite replacers

Ingredient	Addition rate (approx)	Product type	Study description/results	Reference
Sorbate	2600 mg/kg	Bacon	Potassium sorbate used in conjunction with 40mg/kg nitrite. No significant difference (p<0.05) on colour or taste compared to samples containing 120mg/kg sodium nitrite,	Price and Stevenson (1979) as summarised by Gray and Pearson (1984)
	2600mg/kg	Bacon	Potassium sorbate used in conjunction with 40 or 80mg/kg nitrite. No significant (p<0.05) difference in colour or sensory properties compared to samples containing 120mg sodium nitrite.	Paquette et al (1980) as summarised by Gray and Pearson (1984)
	1300 or 2600mg/kg	Bacon	Bacon samples were prepared with 0 or 40mg/kg of nitrite with and without 2 levels of potassium sorbate. Potassium sorbate decreased preference slightly.	Ivey et al (1978) as summarised by Gray and Pearson (1984)
	0.26%	Bacon	Potassium sorbate used in combination with 40ppm nitrite. Colour evaluation and sensory scores showed no practical difference compared to control with 120ppm nitrite.	Shaver (1979) as summarised by Sebranek (1979).
	0-2600ppm	Mortadella	Samples prepared with sodium sorbate only had no cured colour, significantly softer texture and samples were significantly unacceptable. Sorbate in combination with 80ppm nitrite produced acceptable alternatives to samples with 120ppm nitrite alone	Al-Shuibi and Al-Abdullah (2002)

Lactic acid bacteria	Inoculated with Lactobacillus plantarum or Streptococcus faecalis	Bacon	Samples prepared with 40 or 120mg/kg nitrite (control 120mg/kg nitrite) were evaluated for sensory properties. All sensory attributes were judged as similar, except for inoculated samples being less salty than controls.	Traisman (1981) as summarised by Gray and Pearson (1984)
	Inoculated with Pediococcus cerevisiae	Country-style ham	Hams were conventionally cured with or without inoculation with bacteria. Hams were judged to have similar flavour attributes with or without inoculation	Bartholomew and Blumer (1977) as summarised by Gray and Pearson (1984)
Vegetable juice powder (VJP) and starter culture	VJP at 0.2-0.4%. 0.0256% CS 299 Bactoferm™	Cooked frankfurter-style sausages	Raw sausages held at 38°C for 30 or 120 minutes. Samples comparable in colour, oxidation and sensory measurement to sodium nitrite control. Residual nitrite was found to be higher (24.5 and 46.0ppm) after 120 minutes incubation compared to 30 minutes (5.6 and 7.7ppm).	Sindelar et al(2007a)
	VJP 0.2-0.35%.	Hams	Incubation times of 0 or 120 minutes before cooking. Incubation time and VJP concentration did not alter cured colour. Residual nitrite was 7.2-21.3ppm after 90 days compared to 34.1ppm in the nitrite-added controls. Sensory evaluation stated that higher celery powder resulted in vegetable aroma.	Sebranek and Bacus, (2007)
Celery powder and cherry powder	0.28% cherry powder	Cured pork product	Cherry powder samples reduced residual nitrite by 50% compared to control without cherry powder. Product showed similar properties such as colour and oxidation	Baseler, (2007) as summarised by Sebranek and Bacus, (2007)

Lycopene	32.6-38.0mg/kg lycopene as sun dried tomato, tomato paste or crystalline lycopene	Meat farce	Crystalline lycopene samples had the reddest hue and less rancidity. Acidic nature of tomato resulted in reduced microbial growth.	Osterlie and Lerfall (2005).
CCMP	12-18ppm	Pork samples	Colour measurement data suggest that red colour is not significantly different to the nitrite cured controls. A slightly darker colour was noted.	Pegg and Shahidi (2000).
NaCl	13%	Bacon	Samples scored the lowest on preference rating compared to nitrite controls and samples treated with ascorbate and phosphate. Freshly cooked samples described as bland, while 24h chilled samples described as unpleasant, rancid flavour.	Tichivangana et al (1984).
NaCl, tripolyphosphate and sodium ascorbate	13% NaCl 0.1% phosphate 0.1% Ascorbate	Bacon	Nitrite treated samples scored significantly higher than ascorbate and phosphate samples. Samples described as having a juicy flavour, reduced rancidity but weak bacon flavour/aroma.	Tichivangana et al (1984).

5.1 Salt

High intake of salt has been linked to cardiovascular disease, which has resulted in a move to reduce the amount of salt intake (www.salt.gov.uk), resulting in a limited market for products high in sodium chloride Safe products can be produced using salt if a water activity of less than 0.92 is produced (Kemp, 1982). Sea salt is an ingredient that has been found in uncured meat products; however, the nature of sea salt depends on its origin. For example Mediterranean Sea salt is reported to contain 1.1ppm of nitrate and 1.2ppm of nitrite (Sebranek and Bacus, 2007). Some salt may therefore contain natural nitrite and nitrate that can help produce the cured colour and flavours and indeed, historically, meat curing was based on nitrate impurities in salt used to preserve the meat (Sindelar et al, 2007b, Shahidi and Pegg, 1993). Kemp (1982) summarises that country hams, made using a mixture of salt and sugar can produce acceptable products, although nitrate improves colour and flavour, but that bacon needs nitrate or nitrite for acceptable colour and flavour to be achieved.

Sodium chloride also tends to promote lipid oxidation, increasing the unacceptability of products (Pierson and Smoot, 1982). Salt also produces a dark or grey colour through oxidation of myoglobin to metmyoglobin (Wirth, 1991). The degree of production of a grey colour can depend on the diameter of the product, sausage for example, and the coarseness, with thin sausages having an acceptable red colour when coarsely mixed, although thick sausage will have a grey colour inside (Wirth, 1991). It has been reported that salt concentration of less than 10% in combination with lower nitrite, pH and thermal processing can produce acceptable and safe products (Sofos and Busta, 1980). Paradoxically, nitrite can be used to offset the unwanted dark colour that is produced from the use of salt.

Sugar can be used in cured meat systems to add flavour to products as well as to decrease the negative flavour associated with high levels of salt (Sofos and Busta, 1980). This may be why forms of sugar and concentrated sugar have been found in more 'natural' cured meat applications as described above.

Suitability

Salt on its own would not give the pink colour and flavour associated with cured meats and, at levels required for FSA salt targets (FSA, 2009), would have the potential to decrease the microbial safety of cured meat products, if no additional preservatives are used in the product formulation or the shelf-life is not adjusted. The appearance would not be that known and expected by the consumer and this may affect their purchasing decision. There would be labelling implications regarding the description of the product. which would have to be addressed.

5.2 Sorbate

Potassium and other sorbates are a salt form of sorbic acid, are collectively known as Sorbates and are effective against yeast and moulds. Sorbates are similar to benzoates and naturally found in fruit and vegetables. The potassium form is generally used as it is very soluble in water, and therefore can be incorporated in normal meat brines (Sebranek, 1979). The use of sorbates as an antimicrobial agent is discussed in section 4 of this report.

Studies conducted on bacon using potassium sorbate with low levels of nitrite have shown some success, producing products of acceptable colour and taste (Gray and Pearson, 1984). A study conducted on the use of sodium sorbate concluded that the complete replacement of nitrite with sodium sorbate is not possible, with sorbate only samples being significantly unacceptable, increasing rancidity (Al-Shuibi and Al-Abdullah, 2002). This study, however, concluded that the partial replacement of nitrite with sodium sorbate (1000-2600ppm) can produce acceptable alternative products, with a reduction of sodium nitrite to 80ppm. Previous studies have concluded that nitrite levels of 40ppm with 0.26% potassium sorbate and 550ppm of ascorbate can be used to produce an acceptable bacon product (Sofos and Busta, 1980). A previous study conducted did show issues with allergic reactions to sorbate used as a nitrite alternative in meat, which caused many to disregard its use (Ranieri, 1979). However it is thought that this reaction may have been contributed to by the number of samples panellists had to consume, up to 30 slices a day. (Gray and Pearson,1984).

Suitability

Sorbates are not currently permitted as additives in any organic products and their permitted uses in non-organic meat products are very restricted. They are permitted in paté and in jelly coatings of cooked, cured or dried meat products at up to 1,000mg/kg (optionally in combination with p-hydroxybenzoates). They are also permitted as a surface treatment for dried meat products, with the upper limit governed only by good manufacturing practice, achievement of the intended purpose and not misleading the consumer. In this case, sorbates may be used in combination with benzoates and/or p-hydroxybenzoates.

5.3 Benzoate

Benzoic acid is found naturally in foods, particularly in berries. The salt form of sodium benzoate is preferred for use in food as it is a water soluble, odourless powder. Its main function is to inhibit the growth of yeasts and moulds, acting as an antimycotic agent (Davidson et al, 2002). It is most effective in acidic conditions at a pH range of between pH 2.5-4.0. The use of benzoate as an antimicrobial agent is discussed in section 4 of this report

Suitability

Benzoates are not currently permitted for use as additives in any organic products and, as far as conventional meat products are concerned, they are only permitted in the surface treatment of dried meat products (see comments above in relation to permitted uses of sorbates).

5.4 Lactic acid bacteria

Lactic acid bacteria can reduce the pH of food systems by producing acid from fermentable carbohydrates such as dextrose (Anon, 1992). The bacteria can therefore be added to meat products with a fermentable carbohydrate as a form of nitrite alternative. The antimicrobial action of lactic acid bacteria is discussed in section 4 of this report.

Lactic acid has been used in meats to produce fermented sausage, with the lactic acid providing characteristic flavours (Pierson and Smoot, 1982). In bacon, as described by Gray and Pearson (1984), this technique can be used to reduce the residual nitrite in the final product (through the reduction in pH) and therefore reduce the N-nitrosamine levels when cooked. It is also suggested that the slow production of acid when using lactic acid bacteria can be an advantage, allowing nitrite levels to deplete slowly (Sebranek, 1979). A point to consider when using lactic acid bacteria is consistent pH control, with variability between starter cultures and the environment

(Sofos and Busta, 1980). Bacon containing low concentrations of nitrite (down to 40mg/kg) and lactic acid producing bacteria are said to produce acceptable flavours (Assembly of Life Sciences, 1982).

Suitability

The legal status of lactic acid bacteria used in this application is a difficult area and the whole subject of the use of microbial cultures as food additives was considered by the Standing Committee on the Food Chain and Animal Health (Section Toxicological Safety of the Food Chain) (Sanco 2006) in December 2006. The Committee commented on a draft paper on this subject which included the following criteria for determining when a culture was being used as an additive (the third listed criterion is probably the most relevant here and if applicable would mean that specific cultures would need to be authorised as additives for organic meat products before they could be so used):

- Cultures which are added at the beginning or early stages of manufacture and which contribute to the characteristic nature of the food would not be considered as food additives. Examples would be starter cultures used in cheese, yoghurt or dried sausage production.
- Cultures which are used during the manufacture of foodstuffs and which contribute to the characteristic nature of the food would not be considered as food additives. An example would be cultures applied to the surface of a ripening cheese which contributes to the development of the characteristic nature of the cheese (production of cheese rind).
- Cultures which are added for a specific technological effect (such as preservation) would be considered as food additives. Examples could be the use of cultures on cooked or raw meat/shellfish etc. Also included in this example would be the addition of cultures to prepared foodstuffs whereby the culture is intended to act as a preservative.
- Cultures which are added to food but which are not added for a technological function would not be considered as food additives. An example would be the addition of cultures to a yoghurt or dairy drink whereby the cultures are added for a probiotic effect in the consumer.

There is no evidence that this draft paper has been further developed since the December 2006 meeting.

5.5 Vegetable ingredients and extracts

Nitrates are part of the nitrogen cycle in nature and therefore widely found in plants and soil (O'Donnell, 2009). The highest levels of nitrate in plant materials is generally found in leaves, with lower levels in seeds and tubers (EFSA, 2008). High levels (1500ppm and 2800ppm) have been found in celery, lettuce and beets (Sebranek and Bacus, 2007). Celery is a common choice in 'natural' meat products as it has little pigment and a mild flavour (Sebranek and Bacus, 2007).

To naturally cure meat, a source of nitrate such as vegetable powders, juice and concentrates should be used in combination with nitrate reducing bacterial cultures to produce a standard cured meat product (O'Donnell, 2009). These include the organisms *Staphylococcus xylosus* or *Staphylococcus carnosus* (Sebranek and Bacus, 2007). *Staphylococcus carnosus* is used widely in meat products, as it releases a reductase enzyme that reduces the nitrate to nitrite and is subsequently killed on cooking (O'Donnell, 2007).

The holding time and temperature of the incubation process can create different results depending on the application (see Table 5). A temperature range of 38-42°C is recommended as the optimum holding temperature in cooked products (Sebranek and Bacus, 2007). In smaller diameter products such as frankfurters, where heating occurs quickly, an additional processing step allowing time for the bacteria to convert nitrate to nitrite before high temperature heating may be needed (O'Donnell, 2007). Larger products such as hams, may not need an incubation time as the heat will penetrate more slowly allowing the reduction of nitrate to occur before higher temperatures are reached (O'Donnell, 2007). Good distribution of the starter culture and the nitrate source needs to be attained to allow even curing of the product (Sebranek and Bacus, 2007).

A study was conducted investigating the use of cherry powder, in conjunction with celery powder, as a nitrite alternative (Table 2). Cherry powder is high in ascorbic acid, which can reduce nitrite with little effect on pH (Sebranek and Bacus, 2007). Processing issues that may arise from the use of these ingredients in liquid form is the addition of added water to the product and the low shelf-stability of the vegetable juice ingredient, with many supplied in frozen form (Sebranek and Bacus, 2007).

One of the dangers with using natural nitrate sources such as vegetable juices or extracts is that it is difficult to control final nitrate and nitrite levels present in the solution and therefore to control residual nitrite levels in the product..

Suitability

For the legal situation regarding the use of these ingredients, please refer to :
Section *2.3. "Legal position of possible alternatives to nitrite"*
This system does not lend itself to dry curing.

5.6 Acids

Acids such as vinegar and lemon juice can be used to decrease the pH of samples, which can increase nitrite reactions although acidic conditions will shift the equilibrium of nitrite and nitrous acid in favour of nitrous acid. Also it is stated that a decrease in pH by 0.2units will double the rate of colour formation (Sebranek, 1979). The use of a sodium polyphosphate and sodium bicarbonate blend has been suggested for use as it produces more acidic conditions in meat than phosphates alone (Duxbury, 1985). This acidity may affect the texture of the product in organic or natural meats which do not use added phosphate to help moisture retention of samples, where low pH brines (<5.5) are generally undesirable (Sebranek and Bacus, 2007). A study using tomato based products containing lycopene was found to retain red hue, reduce rancidity and in some products control microbiological activity by lowering the pH (Osterlie and Lerfall, 2005).

Suitability

The studies above suggest the use of acid can help reduce nitrites rather than replace them. Further work would be required.

5.7 Cooked cured-meat pigments

Studies have investigated the use of natural cooked cured-meat pigment (CCMP) which can create the characteristic colour of cured products (Wettasinghe and Shahidi, 1997). CCMP can be prepared from haemoglobin or haemin (e.g. animal red blood cells) and nitric oxide, with the addition of ascorbic acid before use to eliminate traces of nitrite (Shahidi and Pegg, 1994). It can be produced from animal blood, a large by-product of abattoirs (Pegg and Shahidi, 2000). CCMP however is not a stable pigment and requires stabilising through encapsulation, modified atmosphere packaging or a reducing agent (Shahidi and Pegg, 1992 and Shahidi, 1991). Encapsulation methods include using modified starch (Shahidi and Pegg, 1995).

CCMP has also been shown to provide some antioxidant effect, which will help with reducing lipid oxidation (Shahidi and Pegg, 1995). Once incorporated into a product it shows similar stability under fluorescent lighting to products cured using nitrite (Shahidi, 1991). Studies have shown that the use of CCMP in combination with nitrite-free ingredients such as antioxidants and antimicrobials can recreate the colour, flavour and bacterial stability of standard meat cured with nitrite, with no nitrosamines detected (Shahidi and Pegg, 1994 and Shahidi and Pegg, 1993, Shahidi et al 1988). In pork 6-12ppm of CCMP is reportedly required to produce the cured meat colour (Shahidi and Pegg, 1993).

Suitability

These studies were carried out in comminuted meat systems and it is not established whether they would be acceptable in whole muscle products.

5.8 Antioxidants and sequestrants

Antioxidants and sequestrants are used in cured meat products to slow down lipid oxidation and rancidity. Ascorbate is used in nitrite cured meat products and is believed to have three functions (Sofos and Busta, 1980).

- Accelerates curing reaction
- Stabilises cured colour
- Decreases rate of nitrosamine formation by inhibiting its formation and decreasing residual nitrite

Sodium ascorbate can also be used as an antioxidant in meat products, having an effect in combination with sodium chloride and sucrose for 3 weeks of storage, after which oxidation is increased (Shahidi et al, 1988, Yun, et al, 1987).

Phosphate can chelate metal ions that catalyse lipid oxidation, and when combined with ascorbates can act synergistically in slowing lipid oxidation (Tichivangana et al, 1984).

Shahidi et al (1992) state that BHA (butylated hydroxyanisole) and TBHQ (tert-butylhydroquinone) at 30ppm effectively slowed oxidation over a 5 week period at

4°C. They also describe the successful use of sequestrants such as phosphates and EDTA (ethylenediaminetetraacetic acid) alone or in combination with antioxidants such as BHA, TBHQ or plant phenolic compounds, having a positive influence on sensory characteristics. A variety of studies have been done on various combinations of antioxidants; these are summarised in Pegg and Shahidi (2000).

O'Boyle et al (1990) state that sodium ascorbate and sodium triphosphate together produce low TBA values and with phenolic antioxidant TBA values are excellent. Yun, et al (1987) state that a combination of antioxidants and chelators can match the action of sodium nitrite on flavour and oxidation in cooked pork.

Tocopherol can prevent the formation of nitrosamines in meat products. α-tocopherol disperses well during cooking of bacon (Sebranek, 1979). It has been suggested that 250-550ppm significantly lowers nitrosamine levels in fried bacon (Ranieri, 1979). As α-tocopherol is lipid soluble, it may need to be incorporated into the meat using emulsifiers in the cure, or applied directly to the surface of bacon, for example as a spray (Assembly of Life Sciences, 1982). The use of antioxidants such as BHA and BHT may be undesirable however, as they have been linked to carcinogenic activity (Pegg and Shahidi, 2000).

Work on the use of spices and herbs as natural antioxidants have shown that they can reduce rancidity, but their effectiveness is dependant on the food matrix, concentration and susceptibility to food processing (Pegg and Shahidi, 2000). In a pork product, clove, sage, rosemary and oregano were effective at slowing oxidation (Pegg and Shahidi, 2000). The use of spices may also add undesirable flavours to the product depending on the application.

The compounds with antioxidant activity in rosemary extract are mainly phenolic compounds, flavonoids, diterpenoids and triterpenes (EFSA, 2008). The most active components are the two phenolic compounds carnosol and carnosic acid (Frankel et al, 1996). Both compounds have shown the ability to chelate some metal ions and be effective scavengers of peroxyl radicals formed during propagation reactions in autoxidation. Rosmaridiphenol has shown antioxidant activity similar to that of BHT (Shahidi et al, 1992). Studies have shown that in some products carnosic acid has stronger antioxidant activity than carnosol (Yanishlieva-Maslarova, 2001, Frankel et al 1996).

Suitability

Further work would be required.

5.9 Colourants

Colours used as a partial replacement for nitrite include erythrosine and betalains. It has been suggested that betalains, the pigment found in beet, has the highest potential in meat products (Sebranek, 1979). The betalains are water soluble pigments. The two main edible sources are beets and, more recently, the prickly pear. The betalains can be divided into two structural groups: the red-violet betacyanins and the yellow betaxanthins (Herbach et al, 2006).

The betacyanin pigment in red beets (betanin) has been used extensively as a colouring in the form of beetroot juice since the eighteenth century. Some varieties of beetroot can contain up to 200mg/100g of betacyanins making it an excellent source (Henry, 1992). Betalain is sensitive to heat, light, moisture and oxygen. It is stable to pH in the range of 3 to 7 (greatest stability at pH 4.5).

Studies summarised by Pegg and Shahidi (2000) state that acceptable sausages were produced with similar colour values measured using Huner L, a, b colour values, although lower L values were observed, suggesting a darker colour. Sensory panellists were able to detect flavour and colour differences between the betalain samples and the nitrite controls. Other studies have been undertaken using natural pigments with or without the addition of nitrite, with betalain again showing the highest consumer preference (Pegg and Shahidi, 2000).

Suitability

Further work would be required

5.10 Irradiation

Irradiation is when food products or ingredients are exposed to ionising radiation and it can be used for microbial decontamination to extend product shelf-life (Shahidi, 1992). Irradiation can inactivate *Clostridium botulinum* and therefore reduce the amount of nitrite needed in the system to that needed to give the distinct colour and flavour of cured products (Sebranek, 1979, McCormick, 1982).

Irradiation levels as low as 7.5kGy can be used to eliminate spoilage organisms, with sterilisation doses reaching 25-30kGy (McCormick, 1982). Positive sensory evaluation scores have been reported on bacon irradiated without the use of nitrite, with high flavour, odour and colour scores, even with a red/brown colour produced after cooking (McCormick, 1982). It has been reported that irradiation can cause an increase in oxidative stability of treated meat (Shahidi, 1992). Irradiation is also described as creating a reduced pink-cured colour in samples using sodium nitrite or CCMP curing alternative, although a positive effect on flavour stability was found (Shahidi, 1992).

Suitability

Irradiated products would not be allowed under the organic regulations

5.11 Lactate

Lactates tend to be added to foods for their taste, buffering ability and humectant properties (Luck and Jaeger 1997 and Davidson *et al* 2005). Lactates also have a preservative action, and the literature indicates that *C. botulinum* is inhibited by lactic acid and its salts (see section 4)

Suitability

Under the terms of Regulation 889/2008, lactic acid is currently permitted as an additive in the production of organic foodstuffs of either plant or animal origin, with no specific upper limit of usage set (usage governed only by good manufacturing practice, achievement of the intended purpose and not misleading the consumer). In addition, sodium lactate is permitted in organic milk-based products and organic meat products, again with usage limited only by good manufacturing practice etc.

5.12 Nisin

Nisin is not currently permitted as an additive in the production of any organic products. As far as conventional products are concerned, it is permitted in only very restricted uses, which include no uses in meat products.

5.13 Conclusion

This review has found that there is no single alternative to nitrite available that can produce all the cured characteristics including microbial stability, colour and flavour. Products can be produced using more natural sources of nitrate but a combination of alternatives would require an antimicrobial agent and a colour and flavour element. Much research, however, is required in this area as studies investigating a combination of alternatives gave variable quality results. Many alternatives reviewed were for a reduction in the amount of nitrite in meat products rather than the total replacement, concentrating on reducing the risk of nitrosamine formation.

Products made without nitrite or suitable alternatives would be expected to have a shorter shelf life, be grey or dark in colour and require very high standards of hygiene throughout the production and distribution process, and may not remain safe if abused by the consumer

The answer to nitrite free cures would appear to lie in the development of composite mixtures.

6. EFFECT ON INDUSTRY OF THE WITHDRAWAL OF THE USE OF NITRATES /NITRITES IN ORGANIC MEAT

6.1 The marketplace

Food provenance, i.e. the origin of the food, has become increasingly important in the UK marketplace. More than just the geographic source of a product or it's ingredients, issues such as animal welfare, food miles, carbon footprint, fair trade, production and farm assurance schemes feature prominently in the media and have become a feature of a food purchase decision for the consumer.

Also of importance, British food and local food appeals to those consumers who prefer to buy local food where possible, supporting local business and benefiting the environment. This is supported by the government's Food 2030 (Defra, 2010) strategy with a vision to move towards a sustainable, secure and healthy food system which would be resilient, profitable and competitive. Thus agriculture plays an important part in the delivery of this strategy and within this sits organic production systems.

After nearly two decades of growing popularity, sales of organic food, drink and other products fell by 12.9% to £1.84 billion in 2009 (Soil Association 2010) with difficult trading conditions in common with much of the rest of the economy being cited as the reason. Organic sales fell across all the major retailers and in the independent sector.

Fresh meat, which accounted for a 5% share of the total UK organic market, saw a drop of 22.7% of sales, thought to be a result of people trading down to save money, with some consumers switching from expensive cuts to cheaper cuts, from red meat to white and from organic to non-organic.

Organic pork production fell significantly, thought to fuelled by high feed prices at the start of the year and nervousness about the economy, resulting in many retailers offering a reduced product range, eliciting the comment that the organic pig supply chain, as with the non-organic pig supply chain, is afflicted by cycles of "boom and bust". As the economics of organic cured meat production rely on carcass balance, a significant reduction in pork production may have had an effect on cured meat sales.

However, the Soil Association, suggesting clear signs of a revival in the organic market, predicts a return to growth in 2010 with a market expansion of 2-5%

Within the marketplace it has been difficult to put a value on organic cured meats in the UK. Some certification bodies base their payments on tonnages, some do not and even with those who do, it transpired during discussion that the set up of their information systems did not lend itself to this calculation.

Figures provided by the Consumer Insights Department at the Agriculture and Horticulture Development Board (AHDB), Stoneleigh Park, Warwickshire are as follows:
April 2009 to April 2010
Organic bacon 1100T (Includes, sliced bacon, chops, steaks, gammon, joints)
Organic sliced cooked ham 91T

These are for own label retail sales in supermarkets in Great Britain. They do not include branded products nor do they include products sold at farmer's shops, farmer's markets, local shops, box schemes, butchers or the food service sector.

Sales of cured meat products in general have fared well over the last recessionary year (the total bacon market has seen a sales increase of 5.2% in the year to April 2010-figure provided by AHDB) as shoppers switch to a cheaper cut of meat for their meal and although independent butchers have seen their market share of bacon sales decline, this is thought to be partly due to shop closures and also aggressive promotions by supermarkets. However, an area where independent butchers continue to excel is own-cured bacon. (A'Court, 2010)

Cured meat products commonly eaten in the UK, and therefore likely to come under the organic label, would probably include mainly bacon, gammon and ham. Reflecting non-organic production, within these product types is expected to be found a large range of cured meat products in the raw and cooked state, fresh and frozen, from a variety of cuts (e.g. back, belly, leg, shoulder), manufactured by various processes (e.g. dry cure, wet cure, traditional processes) and presented in various forms (e.g. joints, slices, cuts and whole muscle) in an array of pack types (e.g. vacuum packed, modified atmosphere packed, over wrapped in trays)

6.2 Certification bodies

In order to use the word “organic”, producers and manufacturers must register with a recognised organic accreditation organisation. Members must follow a strict set of guidelines laid down by law, keep records and submit to regular inspections.
There are several certification bodies in the UK, all of which comply with standards set down by the EU. Approved UK certification bodies listed at www.defra.gov.uk are:

- Organic Farmers and Growers Ltd
- Scottish Organic Producers and Growers Association
- Organic Food Federation
- Soil Association Certification Ltd
- Biodynamic Agricultural Association
- Irish Organic Farmers and Growers Association
- Organic Trust Ltd
- Quality Welsh Food Certification Ltd
- Ascisco Ltd

6.3 Consultation with industry

In order to assess the possible effect on industry of Council Regulation (EC) 834/2007 (EC 2007a) on organic production and labelling of organic products, which requires a re-examination of the use of nitrates and nitrites in cured organic meats with a view to withdrawing these additives by the end of 2010, interviews were carried out by phone, email and in person.

These interviews were carried out with a selection of certification bodies, large, medium and small manufacturers, trade associations, retailers and pig producers. Some of the certification bodies facilitated mailshotting of a questionnaire to their members, and members of Campden BRI thought likely to be affected were also invited to complete the questionnaire. A sample of the questionnaire used can be found in Annex 2.

6.3.1 Awareness

Everyone who replied was aware of the legislation. In particular, the certification bodies felt they had made their members aware of the situation, encouraging those affected to contact Defra to pass on comment. Many had done so and this fact was commented on in completed questionnaires. Most had been aware for some time and expressed surprise that they were still being asked. Some certification bodies collated feedback themselves to pass onto Defra whilst others left the onus on their members to progress the matter. Although the certification bodies had made their members aware of the situation, uptake of this information could not be quantified. Certainly the large-scale manufacturers and major retailers were aware.

6.3.2 Plans

When asked what their plans were, replies from all expressed the hope that the use of nitrates and nitrites would continue to be allowed. Some medium and large manufacturers were looking at vegetable based cures but were uncertain that they would be allowed or had experienced poor organoleptic and shelf life results. Large manufacturers had clearly investigated this and found no suitable alternative and many have lobbied Defra. A smaller manufacturer considered using antioxidants to maintain colour, whilst a small retail butcher was using sea salt without much success. Retailers adopted a lobbying approach for continued use.

6.3.3 Products affected

The products affected are mainly bacon, gammon and ham, cured in a variety of ways. A small manufacturer who owned a farm shop made bacon, gammon and cooked ham. Another small farmer who supplied local customers made dry cured back, streaky and shoulder bacon and bacon joints. A small farmer supplying a local organic box scheme made back and streaky bacon, gammons and gammon steaks. A small retail butcher was involved in dry curing pork loins and bacon. Most sold the products in the chilled state but some very small processors froze their products as they could not sell all their production in the shelf life time span of fresh products.

These activities and products typify small businesses involved with organic cured meats. They include small farmers who process 5 animals per year, small farmers who contribute to local box schemes and those who sell to local customers. Many process in the region of 0.5 to 1 tonne of meat per year. They rely on producing premium products appealing to consumers who choose local and organic products and who often shop at farmer’s markets. They are all traditional British cured meats and rely on optimising carcase use, with the remainder of the animal being used for other products such as sausages. Some sell to their local butcher who will help cure the product and a value to the business given by one such butcher was £5k per annum.

Small businesses and larger farm shops were involved in making a range of bacons, including dry cure, gammon joints, gammon steaks and cooked hams and one was involved in salami manufacture. Tonnages for these companies ranged from 5-15T per year up to 35T for larger processors selling through farm shops.

Larger processors produced a range of cured products, mainly for the major retailers’ own label range, with a small amount for branded products. Again, bacon, ham and gammon featured in the products manufactured, with a wide variety of variations such as dry cure back and streaky bacon, smoked, unsmoked and flavoured bacon, smoked and unsmoked gammons and a large range of hams including baked, roasted and dry cured. Throughput varied from approximately 40T to almost 500 T per annum depending on the company. For some, organic products represented a small fraction of their product portfolio whilst for others it represented a substantially larger portion.

6.4.4 Effect on industry

For those involved in organic production, the premium associated with these products relies on optimising the total carcase and balancing supply with demand. For many cured products this means the back and the leg whilst others may use shoulder and belly. If no longer allowed to carry on using nitrates/nitrites to cure their products, they would have to downgrade the carcase to non-organic status and compete with non-organic cured products, which would not be economical, or stop curing meat.

Different businesses would be affected in different ways if the use if nitrates and nitrites were withdrawn for organic cured meat products. One small farmer felt that this would probably end the retail element of the farming business in which considerable investment had been made over the years. Another would continue making the cured products from organically reared meat but would be unable to label them as organic, feeling strongly that this would indirectly mislead the consumer by not declaring organic, prevent the consumer from making a choice to buy organic, increase confusion regarding traceability and place an unfair economic disadvantage on small local producers, many of whom used traditional dry cure methods.

For one small manufacturer it would cause his business to close down and so is faced with dropping organic status and being forced to change the business completely. A medium sized producer who is investigating alternative methods of making nitrite free bacon felt that he would have to downgrade the leg meat to sausage meat and calculated that this would increase the price of his bacon and sausages by 20%. Even if he could make nitrite free bacon satisfactorily, the loss of revenue from organic ham combined with increased retail prices has been calculated to be 25% of total sales.

Feedback from small producers to some certification bodies indicates that many will simply stop the manufacture of cured products.

For many large manufacturers, organic products represent a small fraction of their turnover with some only making these products to provide a complete product portfolio to a retailer to whom they supply larger volumes of other products. In fact for some it is not cost effective to make certain organic products with little profit and short production run times, but they do so in the interest of client relationships.

Some large manufacturers have indicated that they will cease producing organic cured products should permission to use nitrates and nitrites be withdrawn. These decisions have been made with regret and a not inconsiderable amount of dismay as they feel that by removing nitrite, a safe viable product which is acceptable to the consumer could no longer be made. For larger manufacturers who produce greater volumes of cured products, this is clearly an issue. For retailers, most of whom are supplied by the larger manufacturers, this would mean that in some instances they would be unable to offer the same organic product range to consumers.

6.3.5 Summary

Interviews were carried out with a variety of operators involved in the production of organic cured meats to gauge the effect on industry of Council Regulation (EC) 834/2007 (EC 2007a) on organic production and labelling of organic products, which requires a re-examination of the use of nitrates and nitrites in cured organic meats with a view to withdrawing these additives by the end of 2010.

All of those interviewed were aware of the situation and many had passed comment to Defra. Despite some manufacturers investigating the use of alternative ingredients, all hoped that continued use of nitrates and nitrites would be allowed. Apart from one fermented meat product, all products were typical British cured meats, mainly bacon, ham and gammon in a range of cuts and joints, raw and cooked, smoked and unsmoked. Many, particularly small manufacturers, used dry cure techniques with throughputs varying from a few animals to 500 tonnes per annum total cured meat production.

For all organic cured meat manufacturers, carcase balance was important to the economics of their operation. Not being able to make cured meats meant downgrading the carcase to cheaper products, which affected costs. The effect on small manufacturers included continued production with a reduction in profit, cessation of the retail element of their farming business, dropping organic status, or trying to completely re-invent their business. For larger manufacturers, cessation of organic production was being considered (indications are that large producers known to likely withdraw from organic production would affect approximately 450T of product per annum) whilst others were evaluating alternative ingredients but lobbying for continued use of nitrates and nitrites.

It is difficult to quantify the impact of these regulations should they go ahead. Many small producers trade only in organic products and the effect would be greater in many respects on these operators. In terms of total value, the effect would obviously be greatest on the larger manufacturers and retailers. The cessation of production would also have a knock-on effect on pig producers and certification bodies. Ultimately this could mean less choice for the consumer with perhaps organic cured meats replaced by another premium type product on the supermarket shelf.

Glossary

(cfu/g)	Colony forming Units/gram. An indication of the number of bacteria. 1,000,000cfu/g is a level at which spoilage might be observed.
(d)	Days
(kGy)	KiloGray (radiation unit of measure)
(p<0.05)	Statistically speaking means no significant difference
(ppm)	Parts Per Million
ACMSF	Advisory Committee on the Microbiological Safety of Food
ADI	Acceptable Daily Intake
AHDB	Agricultural and Horticulture Development Board
Anaerobic bacteria	Anaerobic bacteria are bacteria that do not live or grow in the presence of oxygen.
Antibotulinal	Preventing growth of *Clostridium botulinum*
Antilisterial	Preventing growth of listeria
Antimicrobial	Kills or inhibits the growth of microorganisms
Antimycotic	An agent that destroys or prevents the growth of fungi.
Antioxidant	Antioxidants prevent damage caused by oxidation that would normally occur during cell metabolism, neutralizing the damaging effects of free radicals. Antioxidants are added to meat and poultry to prevent or slow the browning caused by the oxidative rancidity of fats.
Ascorbic acid	Acid with anti-oxidant properties
ATP	Adenosine Triphosphate is a multifunctional nucleotide used in cells as a coenzyme. ATP transports chemical energy within cells for metabolism.
Autoxidation	Autoxidation is the spontaneous oxidation of a compound in air.
Aw	Water activity is a measure of water in food that is not bound to food molecules can support the growth of bacteria, yeast, and mould. The term water activity (Aw) describes the ratio of the vapour pressure of a product over the vapour pressure of pure water and is used as a measure of the amount of water that is available for use by microorganisms. Aw is measured on a scale of 0 to 1. The lower the value, the less water is available for growth of microorganisms.

Bacteriocins	An antibacterial substance produced by a strain of bacteria and harmful to another strain within the same family.
BHA	Butylated hydroxyanisole,antioxidant
BHT	Butylated Hydroxytoluene (an antioxidant often used to preserve fats and oils)
CCMP	Cooked Cured Meat Pigment
Chelate	To combine (a metal ion) with a chemical compound to form a ring.
Clean label	Free from chemical additives, natural
Clostridium botulinum	A bacterium that 1) produces spores which are resistant to heating, 2) is capable of producing a powerful potentially fatal neurotoxin and 3) psychrotrophic strains are able to grow at chill temperatures (down to 3.3°C).
Defra	Department for Environment, Food and Rural Affairs
EC	European Commission
EDTA	Ethylenediaminetetraacetic acid (a chelating agent)
EEC	European Economic Community
EFSA	European Food Safety Authority
Endogenous nitrosation	Formation of nitrosamines in the gastric juice of the human stomach
EU	European Union
Food poisoning	Any infectious or toxigenic disease caused by the consumption of food or water.
Food spoilage	Changes in the appearance, taste or smell of food which are organoleptically unacceptable and are caused by the growth of spoilage microorganisms.
FSA	Food Standards Agency
HACCP	Hazard Analysis of Critical Control Points (HACCP) - a quality management system which identifies and evaluates points during production in order to set up measures and control hazards to ensure product safety.
humectant	A substance that promotes retention of moisture.
Hurdle technology	A combination of preservation methods which employs the intelligent combination of different hurdles or preservation techniques to achieve multi-target, mild but reliable preservation effects.

IARC	International Agency for Research on Cancer
L,a,b colour values	Values used to measure colour
Lag time	Initial phase of bacterial growth where the cells may be growing in volume or mass, synthesizing enzymes, proteins, RNA, etc., and increasing in metabolic activity.
Lipids	The fatty substances found in animals and plants
Listeria monocytogenes	A pathogenic bacterium that is capable of growing in chilled foods at temperatures as low as 0^0 C .
Live brine	Curing brine with nitrate reducing bacteria
Log growth of bacteria	Phase of exponential growth
MAP	Modified Atmosphere Packed/Packaging. Modified composition of the atmosphere of a pack to extend shelf life.
mg/kg	Milligrams Per Kilogram
Myoglobin	Protein found in muscle tissue, the chemical status of which affects the meat colour
Na NO2	Sodium Nitrite
Nitrosamines	Potentially carcinogenic compounds produced by reactions of nitrites with amines or amides normally present in the body.
Nitrosatable compounds	Compounds capable of being converted into potential carcinogens
Organoleptic	Organoleptic refers to any sensory properties of a product, involving taste, colour, odour and feel. Organoleptic testing involves inspection through visual examination, feeling and smelling of products.
Pathogenic organisms	Organisms capable of causing diseases
pH	A measure of the concentration of hydrogen ions.The pH scale measures how acidic or basic a substance is. The pH scale ranges from 0 to 14. A pH of 7 is neutral. A pH less than 7 is acidic. A pH greater than 7 is basic.
Probiotics	Live microorganisms administered in adequate amounts which confer a beneficial health effect on the host
Protected Designation of Origin (PDO)	A Protected Designation of Origin (PDO) is part of the Protected Geographical Status system in the European Union (EU). When something is given a Protected Designation of Origin, it means that only items produced in a specific area in a particular way may bear that label in the European market.

Proteolytic bacteria	Bacteria classified by the ability to digest protein
Psychotrophic bacteria	Bacteria that have the ability to grow at low temperatures
Reducing agent	An element or compound that reduces another.
Sequestrant	A sequestrant is a food additive whose role is to improve the quality and stability of the food products. Sequestrants form chelate complexes with polyvalent metal ions, especially copper, iron and nickel, which serve as catalysts in the oxidation of the fats in the food.
Shelf life	Shelf life specifies the period of time which a product can be stored, under specified conditions, and remain in optimum condition and suitable for consumption.
Starter culture	A microbiological culture which performs fermentation.
TBA	Thiobarbituric acid, a measure of rancidity
TBHQ	Terbutylhydroquinone (an antioxidant often used to preserve fats and oils)
UK	United Kingdom
VP	Vacuum Packed/Packaging. Used to extend the shelf life of food by removal of the air surrounding it

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Annex 1

Conclusions from the Group of Independent Experts on "Food Additives and Processing Aids permitted in processing of organic Food of Plant and Animal origin", given at their meeting in July 2007

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Annex 1: Conclusions from the Group of Independent Experts on "Food Additives and Processing Aids permitted in processing of organic Food of Plant and Animal origin", given at their meeting in July 2007

The full conclusions from the Group of Independent Experts on "Food Additives and Processing Aids permitted in processing of organic Food of Plant and Animal origin" (2007b), given at their meeting in July 2007, were as follows:

Potassium nitrates (E252) / Sodium nitrites (E250) for meat production

Function in the products:
Additive functioning as Preservation agent against botulinum
Antioxidant
Colouring
Influences taste

Considerations:
Nitrate is a slow source of nitrite, so the group only considered nitrite.
Nitrite is very reactive and can form nitrosamines during heat treatment. Volatile nitrosamines are
carcinogenic. Reactivity reduces the level of nitrite in the product.
Preservation: Other preservation techniques such as higher salt concentrations, smoking or cooling can replace nitrate if all hygienic standards are fulfilled all the time. In small local productions nitrite may prevent other harmful micro organisms during a short critical period while processing fermented products. If nitrite is banned in organic products within a short time, this may lead to sanitary and quality problems in some small productions due to lack of knowledge about alternative processing techniques. The lower levels in the new regulation also ask for adapted production processes in order to avoid health risks.
Antioxidative effect:
Exclusion of nitrite may reduce shelf life slightly.
Colouring and taste:
Consumers from traditional cured meat products are used to the special taste and colour of nitrite salted meat. Some consumers prefer the colour and taste of organic meat products without nitrite. Other consumers want the same taste and colour from organic and traditional products. It is possible to have the acceptance in the market. An example: In Denmark, where nitrite has not been used for organic meat products for more than 10 years, development of cured, organic meat products of good quality saw a rapidly increasing market.

Recommendations:
Referring to article 3 (c), 4 (b) and 6 (c) the group recommends that nitrate and nitrite within a reasonable time scale should be eliminated from organic meat products. In order to avoid harm to people, this should be done after a general and efficient education programme in alternative processing methods and hygiene to organic meat manufacturers.
Addition of nitrite and nitrate should be kept as low as possible if not eliminated. The added amounts should be regulated, not the residual amounts.

Annex 2

Questionnaire: Review of effect of withdrawal of the use of nitrates/nitrites in organic meats

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REVIEW OF EFFECT OF WITHDRAWAL OF THE USE OF NITRATES/ NITRITES IN ORGANIC MEATS

As part of a review, Campden BRI have been asked by Defra to consult with industry on the on the possible effects of Council Regulation (EC) 834/2007 on organic production and labelling of organic products, which requires a re-examination of the use of nitrates and nitrites in cured organic meats with a view to withdrawing the use these additives by the end of 2010. Currently, these two additives may be used for organic meat products, at up to 80mg/kg indicative ingoing amount and 50mg/kg maximum residual amount.

We would be grateful if you would complete the attached questionnaire and return it SOONEST to e.mulvey@campden.co.uk . If you prefer to discuss, please Tel 01386 842178

1. Are you aware of this legislation? ……………………………………………………………

2. What are your plans? ……………………………………………………………………
……………………………………………………………………………………………
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3. Which products do you currently manufacture that use these additives?
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……………………………………………………………………………………………
……………………………………………………………………………………………

4. How many tonnes of cured (using above additives) organic meat products do you produce per annum? ………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

5. Please indicate the effect on your business should permission to use these additives be withdrawn. If possible, financial implications should be given to the nearest £k).
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6. Any additional comments.
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Annex 3

Salt initiatives in Europe

The changes brought about by the removal of nitrite, in conjunction with reduced salt levels, have the potential to decrease the microbial safety of cured meat products and limit their shelf life. As well as the Food Standards Agency initiative to lower salt levels in the UK (FSA, 2009), there are salt reduction initiatives in Europe, some of which are listed below.

1. EU High Level Group on salt and nutrition

In 2007 it was agreed by Member States to set up an EU framework for salt reduction with a timed plan. The overall goal of the EU framework on salt reduction is to contribute towards reduced salt intake at population level in order to achieve the national or WHO recommendations.

Please see the following:

http://ec.europa.eu/health/nutrition_physical_activity/high_level_group/nutrition_salt_en.htm

The best link from here is to 'National Salt Initiatives implementing the EU Framework for salt reduction initiatives' (link no.3 right at the bottom of the page):

http://ec.europa.eu/health/archive/ph_determinants/life_style/nutrition/documents/national_salt_en.pdf

This document has a table giving data on different EU countries' salt reduction activities in relation to different product types, including meat products. This is followed by information on each country, e.g. the UK is on p91.

Also Note the following statement before the table:

2) Benchmarks & major food categories to focus action on: It would be difficult to establish targets for salt content levels of foods at European level, as starting points may differ considerably from one Member State to another and time required to reach a certain level may vary considerably. Therefore, at European level, a benchmark for overall salt reduction of a minimum of 16% in 4 years against the individual baseline levels in 2008 has been established, applicable to all food products as well as to food consumed in restaurants and catering facilities such as canteens. This is seen as being realistic and achievable in view of experiences with salt reduction in some Member States, meaning that most industry sectors should be well able and thus expected to reach it. Products should be reduced by 4% per year in order to allow consumers to adapt to the slightly decreasing salty taste and in order to ensure continuous progress. Salt reformulation theory is based on the fact that taste can adapt to gradual reductions if those reductions are achieved across the board.

In order to effectively reduce salt intake it is proposed to concentrate activities at a limited number of food categories, 12 have been identified and Member States select at least 5 categories among them for their national plans. The national plans with benchmarks are published.

The twelve categories are:

Bread
Soups
Catering meals
Meat products
Breakfast cereals
Restaurant meals
Cheeses
Fish products
Sauces, condiments, spices
Ready meals
Crisps, savoury snacks
Potato products

For different food categories, a reduction benchmark other than the 16% could be set. National benchmarks and plans could differ, e.g. if one focus food group is already very low in salt then another category may be selected. It is suggested that priority is given to food categories that commonly represent major sources of salt in average diets. Most Member States prefer to work on the food categories; bread, meat products, cheeses and ready meals. Therefore, those categories will be worked on EU level with highest priority. For meat products and cheeses it is acknowledged that sub-categories may have different benchmarks than 16% in 4 years, including reducing variations between similar products. Member States may set individual benchmarks particularly for sub-categories of meat products and cheeses.

At least in the four food categories bread, meat products, cheeses and ready meals the lowest possible salt levels ('best in class' levels) are identified at EU level. Also, Member States may identify 'best in class' products within further food categories. And food producers are encouraged to move towards those 'best in class' levels for all categories of food. If salt reduction reaches the current 'best in class' this is considered as sufficient progress. However, exceeding the 16 % target or improving the 'best in class' levels is strongly encouraged.

2. The 'draft Collated information on salt reduction in the EU April 2008' precedes the above document:

http://ec.europa.eu/health/archive/ph_determinants/life_style/nutrition/documents/compilation_salt_en.pdf

This goes through what each country is doing, although the number of comments specific to 'meat' is fairly low. “Table 2: Compiled Member States responses to salt questions as part of the questionnaire "Implementing the White paper" is of interest.

3 Adoption by Health Ministers of EU Council Conclusions to reduce salt June 2010

On 8 June2010, EU health ministers adopted Council conclusions on action to reduce people's salt intake for better health.

http://www.consilium.europa.eu/showFocus.aspx?id=1&focusId=487&lang=en