United States Department of Agriculture
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edited version - includes only calculations for curing compounds

PROCESSING INSPECTORS' CALCULATIONS HANDBOOK

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Chapter 3

CURING AGENT (NITRITE AND NITRATE) CALCULATIONS

INTRODUCTION

Calculations for curing agents are based on the ***green weight of the meat and/or poultry and/or meat/poultry byproducts (meat block),*** used in the formulation of the product. Because nitrite and nitrate, after being converted to nitric oxide, function by reacting chemically with the meat or poultry myoglobin, the amounts of nitrite or nitrate permitted in the cure must be based on the meat block used in the formulation, ***not*** the finished weight of the product. Using finished weight as the weight base for these calculations would be unacceptable because more curing agent than is allowed could be added to the product. Excess nitrite or nitrate can be toxic.

Either the sodium or the potassium salt of nitrite may be used for curing products, but the weight limitation (based on sodium) is the same for both salts. This limitation was established when the sodium salt was the only one permitted. Later, the potassium salt was allowed to be added at the same level. This level is safe, but rather conservative because potassium is a heavier element than sodium and a greater weight of a potassium salt must be used for the equivalent amount of nitrite or nitrate to be in the product. The bacon regulation, which is more recent than those governing other cured products, also permits both salts, but at different limits for each salt.

There are some recently introduced processes, such as injecting emulsion into the meat or poultry; and there are processes not specifically addressed in the regulations (such as immersion curing of products other than bacon). Nevertheless, the amount of curing solution permitted in these processes is also based on the green weight of the meat or poultry because FSIS believes that all the curing agent used is taken up by the meat or poultry. Table II, on the next page, lists the maximum parts per million (ppm) for each of the four curing agents permitted in products, based on the curing method used. The limits vary among curing methods because the methods differ in the efficiency with which the curing agent is brought in contact with the meat and/or poultry. Limits for nitrite/nitrate combinations and combination procedures (such as pumping and dry curing) are discussed on pages 32 and 33. Bacon, with respect to both curing ingredients and cure accelerators, is discussed on pages 27-31.

TABLE II
MAXIMUM INGOING NITRITE AND NITRATE LIMITS (IN PPM)
FOR MEAT AND POULTRY PRODUCTS*

Curing Agent	Curing Method			
	Immersion Cured	Massaged or Pumped	Comminuted	Dry Cured
Sodium Nitrite	200	200	156	625
Potassium Nitrite	200	200	156	625
Sodium Nitrate	700	700	1718	2187
Potassium Nitrate	700	700	1718	2187

* There are more stringent limits for curing agents in bacon to reduce the formation of nitrosamines. For this same reason, nitrate is no longer permitted in any bacon (pumped and/or massaged, dry cured, or immersion cured). Refer to page 27, Nitrite used in Bacon, for specific information.

As a matter of policy, the Agency requires a ***minimum*** of 120 ppm of ingoing nitrite in ***all*** cured "Keep Refrigerated" products, unless the establishment can demonstrate that safety is assured by some other preservation process, such as thermal processing, pH or moisture control. This 120 ppm policy for ingoing nitrite is based on safety data reviewed when the bacon standard was developed.

There ***is no*** regulatory minimum ingoing nitrite level for cured products that have been processed to ensure their shelf stability (such as having undergone a complete thermal process, or having been subjected to adequate pH controls, and/or moisture controls in combination with appropriate packaging). However, 40 ppm nitrite is useful in that it has some preservative effect. This amount has also been shown to be sufficient for color-fixing purposes and to achieve the expected cured meat or poultry appearance. Some thermally processed shelf-stable (canned) products have a minimum ingoing nitrite level that must be monitored because it is specified as a critical factor in the product's process schedule.

Nitrite and nitrate are not permitted in baby, junior or toddler foods.

NITRITE USED IN CURED, COMMINUTED PRODUCTS

Introduction

The amount of ingoing nitrite permitted in comminuted products, such as bologna, specific and nonspecific loaves, salami, etc., is based on the green weight of the meat and/or poultry and/or meat/poultry byproducts (meat block) used in the product formulation. Shrinkage is not a factor in the calculation. If nitrate is used in conjunction with nitrite, the limits of the two compounds are calculated separately and the permitted maximum of each may be used.

Nitrite Used in Pure Form

! **Calculation Formula**

- $$\frac{\text{lb nitrite} \times 1{,}000{,}000}{\text{green weight of meat block}} = \text{ppm}$$

In comminuted products, this formula can be used to determine:

(1) The permitted weight of the nitrite, if you know the weight of the meat block.

(2) The minimum weight of the meat block that must be used in the formula, if you know the weight of the nitrite being used.

(3) Whether or not a formula will be in compliance with the regulations, if you know the weight of the nitrite and the weight of the meat block.

- **Procedure Table.**

By using the procedure table below, one can determine the amount of nitrite and/or the ppm of ingoing nitrite allowed in a comminuted product.

STEP	PROCEDURE	EXAMPLE
1	Determine the weight of the nitrite in the formulation and identify the meat and/or poultry and/or meat/poultry byproducts that make up the meat block from the label transmittal form or establishment formulation records.	Wiener Formula Beef 230.00 lb Pork 230.00 lb Water 70.00 lb Rework (has nitrite and erythorbate) 50.00 lb Chicken 40.00 lb NFDM 18.00 lb Corn Syrup Solids (CSS) 15.00 lb Salt 5.00 lb Flavorings 4.50 lb Sodium Erythorbate 0.422 lb (6.75 oz.) Sodium Nitrite 0.078 lb (1.25 oz.) Total Batch Weight 663.00 lb

2	Determine the weight of the meat block.	Beef 230 lb Pork 230 lb Chicken + 40 lb Total Meat Block 500 lb
	The following example will illustrate the use of this calculation formula. We know the weight of the meat block and that sodium nitrite is limited to 156 ppm in comminuted products (see Table II, page 12). Substitute these values into the formula and solve for ***n***, the weight of the sodium nitrite.	We have a 500 lb meat block. What is the maximum amount of sodium nitrite that can be added to the formula without exceeding the 156 ppm limit? $\frac{n \times 1{,}000{,}000}{500} = 156$ ppm $n = \frac{156 \times 500}{1{,}000{,}000}$ n = 0.078 lb of nitrite is the maximum amount that could be used in this formula
3	When both factors are known, one can just solve for ***ppm*** and compare the answer with the regulation to determine if the product is in compliance. The product ***is*** in compliance.	We have 0.078 lb of sodium nitrite being added to a sausage formula that has a 500 lb meat block. Will this product be in compliance? $n = \frac{0.078 \times 1{,}000{,}000}{500}$ n = 156 ppm

Note: *If you are unable to solve equations with one unknown, turn to the Appendix, Solving Equations that Have an Unknown Value, pages 115 to 123.*

! **Calculation Formula** (using nitrite limit of ¼ oz per 100 lb of meat block)

Alternatively, one could use the following calculation formula that uses the nitrite limit of ¼ ounce/100 lb of meat and/or poultry and/or meat/poultry byproduct (meat block) to determine the maximum amount of nitrite that can be added to a known amount of meat block.

- $\frac{\text{green weight of meat block}}{100} \times 0.25 = \text{lb nitrite}$

▸ **Procedure Table**

The procedure table below may also be used for determining the amount of nitrite allowed in a comminuted product.

STEP	PROCEDURE	EXAMPLE
1	Determine the weight of the meat block.	Sausage Formula (from page 13) Beef 230 lb Pork 230 lb Chicken + 40 lb Total Meat Block 500 lb
2	Convert this figure into 100 lb units by dividing by 100.	500 lb ÷ 100 = 5.0 units
3	Determine the weight of sodium nitrite allowed by multiplying these units by the decimal equivalent of nitrite allowed per 100 lb. (¼ oz = .25 oz nitrite allowed)	5.0 × 0.25 oz = 1.25 oz or 0.078 lb of nitrite is the maximum amount that can be used with 500 lb of meat and poultry.

! Comment

Any rework in the formulation already containing nitrite shall not be added to the meat block. On the other hand, if the rework does not contain nitrite, the green weight of the meat and/or poultry portion of the rework may be added to the meat block total.

Nitrite in Curing Compounds or Mixes

When curing agents, nitrites and nitrates, are brought into the establishment, they may already be mixed with salt, sugar, corn syrup solids, or monosodium glutamate. If curing agents are mixed with these ingredients, the result is commonly referred to as a curing compound or mix. The curing compound or mix must have the percentage of nitrite and/or nitrate indicated on the container.

! Calculation Formula

▸ $$\frac{\text{lb cure mix} \times \text{\% nitrite in mix} \times 1{,}000{,}000}{\text{green weight of meat block}} = \text{ppm}$$

In comminuted products, this formula can be used to determine:

(1) The permitted weight of the cure mix, if you know the weight of the meat block.

(2) Whether or not a formula will be in compliance with the regulations, if you know the weight of the cure mix, % of the nitrite in the mix, and the weight of the meat block.

! **Procedure Table**

Use the following procedure table to determine the amount of cure mix allowed in a comminuted product and/or the ppm of ingoing nitrite in a comminuted product when nitrite is added via a cure mix.

STEP	PROCEDURE	EXAMPLE
1	Determine the weight of the cure mix added to the formula and identify the meat block from the label transmittal form or establishment formulation records. Identify the percentage of nitrite in the cure mix (the cure mix label may need to be examined).	Cotto Salami Formula Pork 220.00 lb Beef hearts 100.00 lb Beef 60.00 lb Water 50.00 lb Rework (has nitrite) 50.00 lb Salt 7.50 lb CSS 4.00 lb Flavorings 3.00 lb Dextrose 2.00 lb Sodium phosphates 2.00 lb Cure Mix (6.25% sodium nitrite w/salt carrier) 1.30 lb Sodium Erythorbate 0.20 lb (3.20 oz) Total Batch Weight 500.00 lb
2	Determine the weight of the meat block.	Pork 220 lb Beef hearts 100 lb Beef + 60 lb Total Meat Block 380 lb

	The following example will illustrate the use of this formula. We know the weight of the meat block, the percentage of sodium nitrite in the cure mix (6.25%), and that sodium nitrite is limited to 156 ppm in comminuted products. Substitute these values into the calculation formula and solve for ***n***, the weight of the cure mix.	If we have a 380 lb meat block, what is the maximum amount of cure mix that can be added to the formula without exceeding the 156 ppm limit? $\frac{n \times 0.0625 \times 1{,}000{,}000}{380} = 156$ ppm $n = \frac{156 \times 380}{0.0625 \times 1{,}000{,}000}$ n = 0.94 lb of cure mix is the maximum amount that could be used in this formula
3	When all factors are known, one can just solve for *ppm* and compare the answer with the regulation to determine if the product is in compliance. The product ***is not*** in compliance.	We have 1.30 lb of cure mix being added to a sausage formula that has a 380 lb meat block. Will this product be in compliance? $n = \frac{1.30 \times 0.0625 \times 1{,}000{,}000}{380}$ n = 213.81 ppm nitrite

! Comment

The maximum amount of cure mix allowed in a specified amount of meat block can also be determined by first calculating the maximum amount of nitrite permitted in ***pure form,*** and then dividing this amount by the percentage of the nitrite in the cure mix.

Remember that nitrite is limited to 156 ppm or a ¼ oz (0.25 oz) per 100 lb of meat block. Therefore, the maximum amount of nitrite allowed in a 380 lb (from above) meat block would be 0.95 oz (380 ÷ 100 × 0.25) which is equivalent to 0.059 lb (0.95 oz ÷ 16 oz per lb).

Take the percentage of the nitrite in the cure mix and express it as a decimal (move the decimal two places to the left). For example, the cure mix containing 6.25% sodium nitrite would be expressed as 0.0625.

Next, divide the amount of pure nitrite allowed by the percentage of the nitrite in the cure mix. In this case,

0.059 lb ÷ 0.0625 = 0.94 lb cure mix

0.94 lb of the cure mix would be allowed in this batch containing 380 lb of meat or meat byproducts.

Nitrite in Liquid Curing Compounds or Mixes

Liquid cures are a combination of a basic cure mix (dry form) and water. To determine the maximum amount of liquid cure mix permitted in a product formula or whether a product formulated with a liquid cure mix is in compliance, you use the same calculation formula as that in the description for nitrite in cure (dry form) mixes. However, you will first need to calculate the percentage of nitrite present in such a solution.

- **Procedure Table**

STEP	PROCEDURE	EXAMPLE
1	Examine the cure mix formula to determine the percentage of nitrite it contains.	450 lb Salt - 90% 50 lb Sodium Nitrite - 10%
2	Now examine the makeup of the cure solution.	90 lb Water 25 lb Cure Mix 115 lb Total
3	Find the weight of the nitrite used in the liquid cure solution by multiplying the cure mix weight in the solution by the percentage of nitrite it contains.	25 lb Cure Mix × .10 2.5 lb Nitrite
4	Compute the percentage of nitrite in the solution by dividing the weight of the nitrite by the total weight of the solution and then multiply the result by 100.	2.5 ÷ 115 = .0217 (2.17% sodium nitrite in the solution)

5	Now that we know the percentage of sodium nitrite in the liquid cure mix, it can be inserted into the calculation formula (refer to Nitrite in Curing Compounds or Mixes, page 15) and we can solve for ***n,*** the weight of the liquid cure mix.	Using the cotto salami example given earlier, we have a 380 lb meat block. What is the maximum amount of liquid cure mix that can be added to the formula without exceeding the 156 ppm limit? $\frac{n \times 0.0217 \times 1{,}000{,}000}{380} = 156 \text{ ppm}$ $n = \frac{156 \times 380}{0.0217 \times 1{,}000{,}000}$ n = 2.73 lb of liquid cure mix is the maximum amount that can be used with a 380 lb meat block.

NITRITE USED IN CURED, PICKLED PRODUCTS

Introduction

The amount of ingoing nitrite used in pumped, massaged, injected, or immersion-cured products, such as hams, poultry breasts, poultry rolls, corned beef, etc., is based on the green weight of the meat and/or poultry used in the product formulation. Shrinkage is not a factor in the calculation. If nitrate is used in conjunction with nitrite, the limits of the two compounds are calculated separately and the permitted maximum of each may be used (see pages 32 and 33).

Nitrite in Pumped or Massaged Products

! **Calculation Formula**

- $$\frac{\text{lb nitrite} \times \text{\% pump} \times 1{,}000{,}000}{\text{lb pickle}} = \text{ppm}$$

In pumped products, this formula can be used to determine:

(1) The permitted weight of nitrite allowed, if you know the weight of the pickle solution and the percent pump to be used.

(2) The minimum weight of the pickle solution that can be made, if you know the weight of the nitrite and the percent pump to be used.

(3) The maximum percent pump, if you know the weight of the nitrite and the weight of the pickle solution (refer to Chapter 11, pages 80-82, for this type of calculation).

(4) Whether or not a procedure will be in compliance with the regulations, if you know the weight of the nitrite, the weight of the pickle solution, and the percent pump to be used.

! **Procedure Table**

The procedure table below may be used for determining the amount of nitrite allowed in a pumped or massaged product and/or the ppm of ingoing nitrite in a pumped or massaged product. It may also be used to determine the minimum pounds of pickle necessary to produce a pumped or massaged product in compliance with the 200 ppm nitrite limit.

STEP	PROCEDURE	EXAMPLE
1	Determine the weight of the nitrite added to the pickle solution, the total weight of the pickle solution, and the percent pump from the label transmittal form or establishment formulation records. *If any two of these quantities are known, the third can be calculated by substituting the known values into the calculation formula.*	Pickle Formula Water 1310.00 lb Salt 132.00 lb Dextrose 18.00 lb Phosphate 35.00 lb Sodium Erythorbate 3.25 lb Sodium Nitrite 1.75 lb Total 1500.00 lb
2	Two examples will illustrate the use of this formula. We know the weight of the nitrite, the percent pump, and that nitrite is limited to 200 ppm in pumped products (See Table II, page 12). Substitute these values into the formula and solve for ***n***, the lb of pickle.	(A) We have 1.75 lb of sodium nitrite and we want to pump semi-boneless hams at 25%. How much pickle must be made? $200 = \frac{1.75 \times 0.25 \times 1{,}000{,}000}{n}$ $n = \frac{1.75 \times 0.25 \times 1{,}000{,}000}{200}$ n = 2,187.50 lb of pickle solution

	We know the percent pump and the weight of the pickle. Substitute these values into the formula and solve for ***n***, the weight of the sodium nitrite.	**(**B) We want to pump at 25% level and make 1,500 lb of pickle. What is the maximum amount sodium nitrite that may be added to the pickle without exceeding the 200 ppm limit? $200 = \frac{n \times 0.25 \times 1{,}000{,}000}{1500}$ $n = \frac{200 \times 1500}{0.25 \times 1{,}000{,}000}$ n = 1.2 lb of nitrite is the maximum amount that can be added to 1500 lb of pickle that will be pumped into product at a level of 25%.
3	If all 3 factors are known, one can just solve for ***ppm*** and compare the answer with the regulation to determine if the procedure is in compliance. Since only 200 ppm sodium nitrite is permitted, this procedure ***is not*** in compliance.	We have 1.75 lb of sodium nitrite and want to make 1,500 lb of pickle and pump at the 25% level. Is this in compliance? $n = \frac{1.75 \times 0.25 \times 1{,}000{,}000}{1500}$ $n = \frac{437{,}500}{1500}$ n = 291.66 ppm nitrite

Note: *If you are unable to solve equations with one unknown, turn to the Appendix, Solving Equations that Have an Unknown Value, pages 115 to 123.*

Nitrite in Immersed Products

In immersion curing, the submerged meat or poultry absorbs the cover pickle solution, slowly, over a long period of time. There are two recognized methods for calculating the allowable ingoing amount of nitrite in immersion cured products. The method used depends on the mechanism of movement of nitrite within the meat and/or poultry/pickle system and into the meat, meat byproduct, or poultry tissue itself.

! **Method One**

The first method assumes that the meat or poultry absorbs not more than the level of nitrite in the cover pickle. Hence, the calculation for nitrite is based on the green weight of the meat or poultry (as is the case with pumped products), but uses percent pick-up as the percent pump. The percent pick-up is the total amount of cover pickle absorbed by the meat or poultry. It is used in the calculation for immersion cured products in the same way percent pump is used in the (previous) calculation for pumped products.

- **Calculation Formula** (using % pick-up)

$$\frac{\text{lb nitrite} \times \%\ \text{pick-up} \times 1{,}000{,}000}{\text{lb pickle}} = \text{ppm}$$

! **Method Two**

The second method assumes that the submerged meat, meat byproduct, or poultry and the cover pickle act as a single system. Over time, the ingredients in the pickle, such as nitrite and salt, migrate into the meat, meat byproduct, and poultry until levels in the tissue and in the pickle are balanced. This system is actually very complex and dynamic, with components in constant motion, but it will reach and maintain a state of equilibrium. Therefore, the calculation for ingoing nitrite is based on the green weight of the meat block, using the percent added as a relevant amount.

- **Calculation Formula** (using the green weight and pickle weight)

$$\frac{\text{lb nitrite} \times 1{,}000{,}000}{\text{green weight (lb) meat block} + \text{lb pickle}} = \text{ppm}$$

In immersion cured products, this formula can be used to determine:

(1) The permitted weight of nitrite, if you know the green weight of the meat block and the weight of the pickle solution.

(2) The minimum weight of the meat block that can be submerged in the cover pickle, if you know the weight of the nitrite and the weight of the pickle solution.

(3) Whether or not a procedure will be in compliance with the regulations, if you know the weight of the nitrite, the green weight of the meat block to be immersed, and the weight of the pickle solution.

Note: *Method One is used for hams, shoulders, bellies, etc., because it takes weeks for these large items to reach equilibrium. Method Two is primarily used with small items with large surface areas such as pigs' ears, tails, snouts, etc.*

- **Procedure Table**

Use the following procedure table to determine the maximum amount of nitrite allowed in a cover pickle used to cure small items with large surface areas and/or the ingoing ppm of nitrite in a small item with a large surface area that has been submerged in a cover pickle.

STEP	PROCEDURE	EXAMPLE
1	Determine the weight of the nitrite added to the pickle solution, the green weight of the meat, meat byproduct, or poultry and the weight of the pickle solution from the label transmittal form or establishment formulation records. *If any two of these quantities are known, the third can be calculated by substituting the known values into the calculation formula.*	Cover Pickle Formula Water 700.00 lb Salt 70.00 lb Phosphate 18.00 lb Dextrose 9.75 lb Sodium Erythorbate 2.00 lb Sodium Nitrite 0.25 lb Total 800.00 lb
2	The following example will illustrate the use of this formula. We know the weight of the cover pickle, the green weight of the meat byproduct, and that nitrite is limited to 200 ppm in immersion cured products (see Table II, page 12). Substitute these values into the formula and solve for ***n,*** the weight of the sodium nitrite.	We have 800 lb of pickle solution and we want to immersion cure 600 lb of pork snouts. How many pounds of sodium nitrite can be added to the cover pickle without exceeding the 200 ppm limit? $200 = \frac{n \times 1{,}000{,}000}{600 + 800}$ $n = \frac{200 \times 1400}{1{,}000{,}000}$ n = 0.28 lb of nitrite

3	When all 3 factors are known, one can just solve for ***ppm*** and compare the answer with the regulation to determine if the procedure is in compliance. This product ***is*** in compliance	We have 0.25 lb of sodium nitrite and want to make 800 lb of cover pickle, and add 600 lb of pork snouts to the cover pickle. Will this product be in compliance? $n = \frac{0.25 \times 1{,}000{,}000}{600 + 800}$ n = 178.57 ppm nitrite

Note: *If you are unable to solve equations with one unknown, turn to the Appendix, Solving Equations that Have an Unknown Value, pages 115 to 123.*

NITRITE USED IN CURED, DRY PRODUCTS

Introduction

The amount of ingoing nitrite used in dry cured products, such as country ham, country style pork shoulder, prosciutto, etc., is based on the green weight of the meat or poultry in the product formulation. These products are prepared from a single intact piece of meat or poultry that has had the curing ingredients directly applied to the surface, and has been dried for a specified period of time. For large pieces of meat, the curing ingredients must be rubbed on the surface several times during the curing period. The rubbed meat or poultry cuts are placed on racks or in boxes and allowed to cure. Nitrite is applied to the surface of the meat or poultry as part of a cure mixture.

- **Calculation Formula** (using lb of cure mix)

    - Dry cured product formulation compliance can be monitored using the familiar % pump and pounds of pickle equation used in the **Nitrite in Pumped or Massaged Products** section (page 19), substituting "% cure mix applied" for "% pump" and "lb cure mix" for "lb pickle".

$$\frac{\text{lb nitrite} \times \text{\% cure mix applied} \times 1{,}000{,}000}{\text{lb cure mix}} = \text{ppm}$$

▸ **Procedure Table**

STEP	PROCEDURE	EXAMPLE
1	From establishment formulation records, determine the weight of the dry cure mix that will be applied to the meat or poultry.	Dry Cure Mixture Salt 42.5 lb 85% Sugar 5.0 lb 10% Sodium nitrate 2.0 lb 4% Sodium nitrite 0.5 lb 1% Total 50.0 lb 100% Use 4 lb of dry cure mix per 100 lb of ham or pork shoulder
2	Convert the amount of dry cure mix per 100 lb of meat or poultry to a percent. Your answer will be the % applied.	$(4 \div 100) \times 100 = 4.0\%$ dry cure applied
3	When all factors are known, one can just solve for ***ppm*** and compare the answer with the regulation to determine if the product is in compliance. Since nitrite is permitted up to a level of 625 ppm in dry cured products, this product ***is*** in compliance.	We have 50 lb of dry cure mix containing 0.5 lb nitrite applied to hams or pork shoulders at a rate of 4%. Will the product be in compliance? $n = \dfrac{0.5\text{ lb} \times .04 \times 1{,}000{,}000}{50\text{ lb}}$ n= 400 ppm nitrite

! **Calculation Formula** (using green weight of the meat or poultry)

▸ When checking nitrite compliance in dry cured products, you may also use the same equation given in the **Nitrite in Curing Compounds or Mixes** section (page 15).

$$\frac{\text{lb cure mix} \times \text{\% nitrite in mix} \times 1{,}000{,}000}{\text{green weight meat or poultry (meat block)}} = \text{ppm}$$

In dry cured products, this formula can be used to determine:

(1) The permitted weight of the cure mix, if you know the green weight of the meat or poultry and the percentage cure agent in the mix.

(2) Whether or not a formula will be in compliance with the regulations, if you know the weight of the cure mix, % of the nitrite in the mix, and the green weight of the meat or poultry.

- **Procedure Table**

Use the following procedure table to determine the maximum amount of a cure mix that can be applied to the surface of a dry cured product and/or the ppm of ingoing nitrite in a dry cured product.

STEP	PROCEDURE	EXAMPLE
1	Determine the weight of the cure mix applied to the meat or poultry and the weight of the meat or poultry from the label transmittal form or establishment formulation records. Identify the percentage of nitrite in the cure mix (the cure mix label may need to be examined). *If one of these quantities is known, the other can be calculated by substituting the known value into the equation.*	Country Ham Ham 500.00 lb Cure mix (1.00% sodium nitrite) + 20.00 lb Total 520.00 lb Use 4 lb of cure mix per 100 lb of meat or poultry.
2	The following example will illustrate the use of this calculation formula. We know the weight of the meat, the percentage of sodium nitrite in the cure mix, and that sodium nitrite is limited to 625 ppm in dry cured products. Substitute these values into the calculation formula and solve for ***n***, the weight of the cure mix.	If we have 500 lb of ham, what is the maximum amount of cure mix that can be added to the formula without exceeding the 625 ppm limit? $\frac{n \times 0.01 \times 1{,}000{,}000}{500} = 625$ ppm $n = \frac{625 \times 500}{0.01 \times 1{,}000{,}000}$ n = 31.25 lb of cure mix is the maximum amount that could be used in this formula. OR 6.25 lb of cure mix per 100 lb of meat or poultry [31.25 ÷ 5 (100 lb units) = 6.25 lb]

3	When all factors are known, one can just solve for ***ppm*** and compare the answer with the regulation to determine if the product is in compliance. Because dry cured products can contain sodium nitrite up to a level of 625 ppm, this product ***is*** in compliance.	We have 20 lb of cure mix that has nitrite in it at a level of 1.00% being applied to 500 lb of ham. Will this product be in compliance ? $n = \frac{20 \times 0.01 \times 1{,}000{,}000}{500}$ n = 400 ppm nitrite

! Comment

The maximum amount of cure mix allowed in a specified amount of meat or poultry to be dry cured can also be determined by first calculating the maximum amount of nitrite permitted in ***pure form,*** and then dividing this amount by the percentage of the nitrite in the cure mix.

Remember that nitrite is limited to 625 ppm or 1 oz per 100 lb of meat or poultry. Therefore, the maximum amount of nitrite allowed in 500 lb of hams (from page 26) would be 5 oz [(500 ÷ 100) × 1.0] which is equivalent to 0.312 lb (5 oz ÷ 16 oz per lb).

Take the percentage of the nitrite in the cure mix and express it as a decimal. For example, the cure mix containing 1.00% sodium nitrite would be expressed as 0.01.

Then divide the amount of pure nitrite allowed by the percentage of the nitrite in the cure mix. In this case,

0.3125 lb ÷ 0.01 = 31.25 lb maximum cure mix

31.25 lb of the cure mix (nitrite 1.00%) would be allowed in the batch containing 500 lb of hams.

NITRITE USED IN BACON

Introduction

Because of problems associated with nitrosamine formation in bacon, MPI Regulations, section 318.7(b)(1) and (3) prescribe the amounts of nitrite and sodium ascorbate or sodium erythorbate (isoascorbate) to be used in pumped and massaged bacon. For the immersion curing and dry curing of bacon, maximum amounts of sodium and potassium nitrite are prescribed in section 318.7(b)(5) and (6) of the MPI Regulations.

Establishment management must submit pickle formulas and the method(s) of preparing ***pumped and/or massaged bacon*** to the processing staff officer at the appropriate regional office. The pickle formula and targeted percent pump or pick-up must meet the limits listed below. Once the procedure is approved, production may begin.

Regardless of the curing method used, restricted ingredient calculations for bacon are based on the ***green weight*** of the skinless belly. For rind-on bacon, e.g., where the skin is sold as part of the finished product, a restricted ingredient conversion calculation is necessary. ***Nitrate is no longer permitted in any curing method for bacon.***

! **Ingredient Limits**

- ***Pumped and/or Massaged Bacon (rind-off):*** An amount of 120 ppm sodium nitrite (or 148 ppm potassium nitrite), ingoing, is required in pumped and/or massaged bacon, except that 100 ppm sodium nitrite (or 123 ppm potassium nitrite) is permitted with an appropriate partial quality control program, and except that 40 - 80 ppm sodium nitrite (or 49 - 99 ppm potassium nitrite) is permitted if sugar and a lactic acid starter culture are used. ***550 ppm sodium ascorbate or sodium erythorbate (isoascorbate), ingoing, is required in pumped and massaged bacon, in addition to any prescribed amount of nitrite.***

- ***Immersion Cured Bacon (rind-off):*** A maximum of 120 ppm of nitrite or equivalent of potassium nitrite (148 ppm) can be used in immersion cured bacon. ***Note:*** *the calculation method for nitrite in immersion cured bacon is the same as that for nitrite in other immersion cured products. Refer to pages 21-24.*

- ***Dry Cured Bacon (rind-off):*** A maximum of 200 ppm of nitrite or equivalent of potassium nitrite (246 ppm) can be used in dry cured bacon. ***Note:*** *the calculation method for nitrite in dry cured bacon is the same as that for nitrite in other dry cured products. Refer to pages 24-27.*

- ***Pumped, Massaged, Immersion Cured, or Dry Cured Bacon (rind-on):*** The maximum limit for ingoing nitrite and sodium ascorbate or sodium erythorbate must be adjusted if bacon is prepared from pork bellies with attached skin (rind-on). A pork belly's weight is comprised of approximately 10 percent skin. Since the skin retains practically no cure solution or cure agent, the maximum ingoing nitrite and sodium ascorbate or erythorbate limits must be reduced by 10 percent. For example, the maximum ingoing limit for nitrite and sodium ascorbate or erythorbate for pumped pork bellies with attached skin would be 108 ppm [120 ppm – 12 ppm (120 × .10)] and 495 ppm [550 ppm – 55 ppm (550 × .10)], respectively.

When determining ***pumped and/or massaged*** product compliance with the nitrite and ascorbate (or erythorbate) limits, the Agency allows a ***plus or minus*** 20% ppm allowance at the time of injecting or massaging due to variables in pumping procedures, draining, purge, etc.

For example: 20% = 0.20, thus 0.20 × 120 ppm nitrite = 24 ppm

120 ppm	120 ppm
− 24 ppm	+ 24 ppm
96 ppm minimum nitrite	144 ppm maximum nitrite

The same calculation can be done for ascorbate or erythorbate (440 ppm minimum, 660 ppm maximum).

Note: *The additional solution added to the product from the higher effective or actual % pump than the establishment's target % pump would be considered negligible because the finished product weight must return to green weight.*

! Calculation Formulae

- The formula for determining nitrite compliance in a proposed pumped or massaged bacon processing procedure is:

$$\frac{\text{lb nitrite} \times \text{\% pump} \times 1{,}000{,}000}{\text{lb pickle}} = \text{ppm}$$

In pumped and/or massaged bacon, this formula can be used to determine:

(1) The permitted weight of nitrite allowed, if you know the weight of the pickle solution and the targeted percent pump to be used.

(2) The minimum weight of the pickle solution that can be made, if you know the weight of the nitrite and the targeted percent pump to be used (refer to the Procedure Table on page 20 for this type of calculation).

(3) The maximum percent pump, if you know the weight of the nitrite and the weight of the pickle solution (refer to Chapter 11, pages 80-82, for this type of calculation).

(4) Whether or not a procedure will be in compliance with the regulations, if you know the weight of the nitrite, the weight of the pickle solution, and the targeted percent pump to be used.

- To determine nitrite compliance based on the ***effective or actual % pump***, you can use the formula above by replacing the targeted pump with the effective or actual % pump. ***Alternatively***, you could use the following variations to the formula on the previous page:

$$\frac{\text{lb nitrite} \times 1{,}000{,}000}{\text{lb pickle}} = \text{ppm nitrite in the pickle}$$

ppm nitrite in the pickle × effective or actual % pump = ppm nitrite in the bacon

! Procedure Tables

Use the following procedure table to determine compliance of a proposed bacon processing procedure.

STEP	PROCEDURE	EXAMPLE
1	Determine the weight of the nitrite added to the pickle solution, the total weight of the pickle solution, and the targeted % pump from the FSIS Form 10,520-1 that the establishment has prepared.	Pickle Formula Water 1996.3 lb Salt 302.2 lb Sugar 156.3 lb Sodium Phosphate 31.3 lb Sodium Erythorbate 11.4 lb Sodium Nitrite 2.5 lb Total 2500 lb *Targeted pump is 12%*
2	If all three factors are known, one can just solve for ***ppm*** and compare the answer with the regulation to determine if the procedure is in compliance. ***Note:*** *The ingoing ppm of sodium erythorbate can be determined by replacing the pounds of nitrite with the pounds of sodium erythorbate and performing the mathematics.*	We have 2.5 lb of nitrite and want to make 2500 lb of pickle and pump at a level of 12%. Is this in compliance? $n = \frac{2.5 \times 0.12 \times 1{,}000{,}000}{2500}$ n = 120 ppm nitrite (in compliance)

Use the following procedure table to determine the compliance of bacon at the time of pumping and/or massaging. The pickle formula in the procedure table on the previous page will be used as the example in this procedure table.

STEP	PROCEDURE	EXAMPLE
1	Multiply the weight of the sodium nitrite by 1,000,000.	2.5 lb sodium nitrite × 1,000,000 = 2,500,000 ppm nitrite.
2	Divide this figure by the weight of the pickle solution.	2,500,000 ÷ 2,500 = 1000 ppm nitrite in the pickle solution.
3	Multiply this figure by effective or actual % pump to obtain ppm. Refer to Chapter 11, page 78, to learn how to determine the effective or actual % pump (percent gain).	1000 ppm × 0.096 (9.6 % effective pump) = 96 ppm ingoing nitrite in the pork bellies. Product ***is*** in compliance with the 20% ppm allowance.

NITRATE USED IN CURED COMMINUTED, PICKLED, AND DRY PRODUCTS

Introduction

Nitrate is used as a source of nitrite. If nitrate is used as the curing agent, the conversion (reduction) of nitrate to nitrite by bacteria in the meat or poultry is a necessary step in the development of the cured color. The amount of nitrate that is reduced to nitrite is dependent upon the numbers of nitrate-reducing bacteria and several environmental conditions such as temperature, moisture content, salt content, and pH. Hence, the conversion rate and subsequent amount of nitrite that is formed is difficult to control. Similarly, the further reduction of nitrite to nitric oxide, which reacts with myoglobin (muscle pigment) to produce the cured color, is also affected by the same environmental conditions. If nitrite is used as the curing agent, there is no need for the nitrate reduction step, and the development of the cured color is much more rapid.

The poor control associated with the reduction of nitrate to nitrite, coupled with the fact that most processors today demand faster curing methods, has lead to the diminished use of nitrate in meat and poultry products.

Calculations for nitrate are the same as those for nitrite described on pages 11 through 27. Different limits apply, depending upon the curing method used, and are illustrated in Tables I (see page 7) and II (see page 12).

! **Example**

Using the same cure mix formula for dry cured hams or pork shoulders shown in the Procedure Table on page 25, calculate the amount of sodium nitrate. There are 2 pounds of sodium nitrate in 50 pounds of cure mix and the cure mix is applied at the level of 4 pounds per 100 pounds of ham or pork shoulder, or at a 4% level.

- **Calculation**

$$\frac{\text{lb sodium nitrate} \times \text{\% cure mix applied} \times 1{,}000{,}000}{\text{lb cure mix}} = \text{ppm}$$

$$\frac{2 \times 0.04 \times 1{,}000{,}000}{50} = 1600 \text{ ppm sodium nitrate}$$

Since the 1600 pm is less than 2187 ppm (the maximum permitted), the amount of sodium nitrate ***is*** in compliance.

NITRITE AND NITRATE USED TOGETHER IN A SINGLE CURING METHOD

Introduction

When nitrite and nitrate are used together in a single curing method, each one is calculated independently and each one is permitted to be used up to the maximum individual limits listed in Table II (see page 12).

! **Limit**

Although nitrite and nitrate are calculated on an ingoing basis and the calculations are based on the green weight of the meat/poultry, the use of nitrites, nitrates, or a combination ***must not*** result in more than 200 ppm of nitrite, calculated as sodium nitrite, in the ***finished product.*** Therefore establishment operators using both compounds must take care to observe this limit. Violations are determined by laboratory analysis.

! **Control**

Laboratory analyses for nitrite yield varying results because the nitrite reacts at varying rates depending on a number of factors, such as temperature, pH, and duration of storage, and thus becomes unavailable and undetectable by current analytical methods. Also, sodium ascorbate interferes with nitrite analysis. Formulation is therefore the primary control. However, sampling for residual nitrite is still performed, especially where both nitrite and nitrate have been added to the formulation.

NITRITE AND NITRATE USED TOGETHER WITH MORE THAN ONE CURING METHOD

Introduction

Some processors use ***both*** nitrite and nitrate in a cure mix and more than ***one*** curing method for a single product. In these situations, nitrite and nitrate are first calculated independently for each curing method. Each curing agent must be calculated as a percentage of the maximum permitted for the method of curing used, and the total percentage of each curing agent ***cannot*** exceed 100% (see Table II, page 12).

- **Example One**

Westphalian Style Hams are dry cured and then immersed in a cover pickle solution. The sodium nitrite limit for dry curing is 625 ppm and for immersion curing the limit is 200 ppm; and the sodium nitrate limit is 2187 ppm for dry curing and 700 ppm for immersion curing.

If the establishment dry cured the hams with 400 ppm nitrite (see page 27), it has used 400 ÷ 625 or 64% of the maximum amount of nitrite that is permitted in the drying procedure. Since 200 ppm is the maximum amount of nitrite permitted in immersion curing, the establishment can only use 36% (100% – 64%) of that amount of nitrite, or (200 ppm × .36) 72 ppm nitrite in the immersion cure. If the establishment dry cured the same hams with 1600 ppm nitrate (see page 32), it has used 1600 ÷ 2187 or 73.15% of the maximum amount of nitrate that is permitted in the drying procedure. Since 700 ppm is the maximum amount of nitrate permitted in immersion curing, the establishment can only use 26.85% (100% – 73.15%) of that amount of nitrate, or (700 ppm × .2685) 187.95 ppm nitrate in the immersion cure.

- **Example Two**

In Black Forest Brand Hams that are pumped and then immersed in a cover pickle solution, the limits are the same (200 ppm for nitrite, 700 ppm for nitrate). Therefore, if 200 ppm nitrite is used in the pumping process, no additional nitrite is permitted in the cover pickle. If 350 ppm nitrate (or 50% of that permitted) is added to the pump cure, up to 350 ppm nitrate (the other 50%) is permitted in the cover pickle.