Influence of phosphate on heat conductivity of cooked salt-cured meats

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Background: Within the context of EU harmonization, phosphates whose effects in cooked sausages are sufficiently well-known, have also been permitted in the manufacture of cooked salt-cured meats in the Federal Republic of Germany since 15 December 1995. Using phosphates it is possible to considerably improve the water binding capacity of proteins *(FISCHER 1988)*. Because of the changes to additive laws brought in by EU legislation, studies have been carried out on whether the coefficient of thermal conduction is influenced by the addition of phosphate in cooked salt-cured meats. In the literature available to us no mention is made of the coefficient of thermal conduction of cooked salt-cured meats as a function of the addition of phosphate.

Objectives: Material properties play an important part in the calculation of food production processes. If foods are subjected to heating, the specific thermal capacity and the thermal conductivity are significant factors. The thermal conductivity is one of the prime thermal properties for the calculation of heating processes.

Heat transfer: Temperature differences between two media will always even out over time. The second law of thermodynamics applies, which states that heat is only transferred from a body at a higher temperature to a body at a lower temperature. This process is irreversible. There are basically three different means by which heat is transferred: **thermal radiation, conduction and convection.** In solid bodies heat is transferred by conduction. In this context boiled ham can be considered a solid, since the quantity of incorporated liquid is so small that practically no convection takes place.

Coefficient of thermal conduction (λ): If two bodies at different temperatures are separated from each other by a medium, a heat flow will occur from the warmer to the cooler body. This heat flow Q is directly proportional to the temperature gradient at these two boundaries. The proportionality factor k is the thermal conductivity of the medium. This relationship is described by Four's Law.

Cell death of microorganisms by means of heat: The microflora present in the raw material of cooked salt-cured meat mainly consists of Gram-negative rod-shaped bacteria and micrococci, as well as small quantities of fecal enterococci. Lactic acid bacteria, *Bacillus thermosphacta* and Bacillus species as well as yeasts and moulds are only present in small amounts *(WEBER 1996)*. The resistance of various vegetative microorganisms varies considerably *(MÜLLER and WEBER 1996)*.

Methods: Picnic ham (shoulder-cut) and high-quality haunch ham cuts were manufactured. The raw material was cut, the meat sorted, the brine manufactured and tumbling performed under cooling conditions all according to the usual methods of the trade. The brine recipe is given in Table 1. The injected quantity was 20%. The hams were cooked in a water bath (Korimat). The cooking medium was kept at a constant temperature of 80°C during the cooking process. When the core temperature of 72°C were reached, the moulds were cooled in a water bath for 15 minutes and then stored at 0 to –1°C.

The coefficient of thermal conduction in the cooked salt-cured meats was determined using two different measuring instruments:

Method 1: The measuring instrument QTM-D3 (Rapid Thermal Conductivity Meter, Kyoto Electronics) for determining the thermal conductivity works according to the measurement principle of the modified DIN 51 046 method. The probe used was the QTM-PD3 sensor. The values were recorded and analyzed using a data collection program. Duration of the measurements was 60 seconds, each time taking place after a warming-up period of 30 minutes. Four-fold measurements were carried out.

Method 2: The thermal conductivity instrument TK04 from TeKa, Berlin, is based on the unsteady heat flow method. Various probes can be connected for investigating various materials. The special analysis algorithm takes account of the contact resistance between the probe and the sample and allows the quality of the measurement to be checked by means of a graphic program. Each sample was measured in three different places. (10 single measurements at each location).

Results and discussion: It was shown that the coefficient of thermal conduction in boiled ham is influenced by phosphate. Higher values for λ were determined in all hams containing phosphate than in the control samples (Table 2 and Fig. 1).These results were obtained using both the instruments used for registering the thermal conductivity. Moreover, the same result was obtained in both series of tests, i.e. both in the picnic ham and in the haunch ham. All in all there was a slight but definite increase in the coefficient of thermal conduction.

These results permit the conclusion that the thermal diffusivity increases under the addition of phosphate while the other parameters remain the same. This is a beneficial effect. More effective heating improves the microbiological stability and shelf-life of the products. The addition of phosphate in cooked salt-cured meats has a positive influence on the microbiological quality of cooked salt-cured meats by means of improving the coefficient of thermal conduction. The core temperatures required to inactivate microorganisms are reached more rapidly.

The particular parameters responsible for increasing the coefficient of thermal conduction were not determined. However, one cause is certainly the changed water contents. The addition of phosphate improved the water binding capacity of the meat protein, which affected the water contents. Further experiments should be carried out in order to demonstrate the impact on the coefficient of heat conduction of adding phosphate to cooked salt-cured meat and to the raw material. Practically oriented tests demonstrating the effects of changed λ values on the duration of the heating process would also be valuable.

Conclusions: The influence of a phosphate additive on the thermal conductivity of cooked salt-cured meats was examined. After adding 20% brine, the designated raw material was tumbled and heated to a core temperature of 72 °C. The coefficient of thermal conduction in the cooked salt-cured meat was determined by means of two different measuring instruments (Rapid Thermal Conductivity Meter QTM-D3 from Kyoto Electronics, as well as the thermal conductivity instrument TK04 from TeKa, Berlin). Treatment of cooked salt-cured meat with phosphate caused a clearly lower level of heat loss as well as an increase in the coefficient of thermal conduction (maximum 0.07 [$W\ m^{-1} K^{-1}$], average 5%). This slight but definite improvement in thermal conductivity observed in all samples has a positive effect on the microbiological quality of cooked salt-cured meats, since the thermal diffusivity in the meat increases. The core temperatures necessary to inactivate microorganisms are reached more rapidly. This can contribute to an improvement in the microbiological stability and an extension of the shelf-life of the products. Further tests should be carried out to demonstrate the impact of phosphate additives on the coefficient of thermal conduction in cooked salt-cured meats.

Pertinent literature

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Table 1: Recipe of the brine used in manufacturing the cooked salt-cured meats

	phosphates without	phosphates with
Nitrite curing salt [%]	*11.40*	*11.40*
Eldo-Lak Gold [%]*	*5.00*	*5.00*
*Phosphate** [%]*	*-*	*5.36*
Drinking water	*83.60*	*78.24*

**** Eldo-Lak Gold (Hagesüd, Type no. 56063) consisting of E300 l-ascorbic acid, E 301 sodium L-ascorbate, E 621 sodium glutamate, saccharine, spice extracts, water. ** Combination of Na-and. K-diphosphates E 450, pH 7.0***

Table 2: Thermal conductivity [$W\ m^{-1}\ K^{-1}$] in cooked salt-cured meats with and without the addition of phosphate

Picnic ham	*Instrument QTM*	*without*	**0.4848**
		with	**0.5548**
	Instrument TK04	*without*	**0.541**
		with	**0.550**
Haunch ham	*Instrument QTM*	*without*	**0.5997**
		with	**0.6182**
	Instrument TK04	*without*	**0.562**
		with	**0.572**

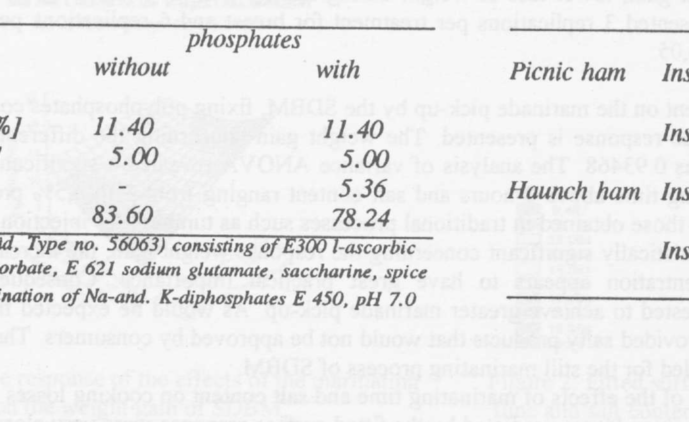

Fig. 1: Measurements of thermal conductivity in cooked salt-cured meats, manufactured with and without the addition of phosphate