THE INFLUENCE OF DIFFERENT SALT CONCENTRATION AND RESIDUAL CONCENTRATION OF CURING SALTS ON THE MICROBIOLOGICAL CHARACTERISTICS OF DRY-CURED HAMS

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Key words: dry-cured hams, microbes, curing salts, brine concentration, traditional production

Background

In the curing process of traditionally made hams at a small scale, the material quality, the production hygiene as well as the continuity of the cooling chain are decisive. The proper fermentation process is secured by means of the application of starter bacterial cultures and by such a selection of the concentration of sodium chloride and curing salts that the water activity in the inner layers of meat was lowered as soon as possible and that the concentration of nitrites exceeded the level of active protection against the development of pathogenic bacteria. In the curing process of traditionally made hams at a small scale the most difficult process to be controlled is the process of salting and curing. The sodium chloride and curing salts - nitrites and nitrates are spread over the open surface of ham muscles in excess. After a certain time the remaining excess of the said substances is being removed assuming that their part, which has been absorbed by the meat is sufficient to achieve proper level of sodium chloride concentration and curing salts in the meat. The effective sodium chloride and curing salts diffusion speed depends on many factors, mainly on their initial concentration, size of hams, area of open muscles and inner and inter-muscle fat saturation.

Objective

There were 19 dry-cured hams manufactured in pilot conditions boneless, formed similarly to Westfalen type hams. The hams of intentionally differentiated weights were superficially salted and cured with dry rock-salt and corning salt doses comprising nitrites and nitrates in the ratio of 1 : 1, in the different volume for different variants and namely: D_1 = 300 mg/kg (Variant I), D_2 = 600 mg/kg (Variant II), D_3 = 1200 mg/kg (Variant III), D_4 = 2400 mg/kg (Variant IV). The starter culture Staphylococcus carnosus of high tolerance for sodium chloride and low temperatures has also been applied. The curing process has been performed at the temperature of 6-8°C and at the relative humidity of 85-90% in the period of 53 days. After curing, the hams have been rinsed with running water, dried, weighed and placed in the room at the temperature of 10-12 °C and at the relative humidity of 90%, lowered gradually to 75%. The process has been continued monitoring the weight losses every 3-4 days until the weight of 78% of the original one has been achieved. Then the finished product has been closed in barrier bags or covered with fat and spicy paste and stored in the period of 6 months. The specific production process together with the different factors like original weights, pH of hams, concentration of curing substances and methods of protection against drying resulted in the different conditions of the curing process and in the different physical and chemical parameters characteristic for the medium of microbe development.

Methods

The samples for microbiological test have been taken in a sterile way from the outer and inner layers of hams. The microbiological tests covered the determination of the Total Aerobic Count, Staphylococcus Count, Lactic Acid Bacteria Count, Yeasts Count and Moulds Count and tests for presence of Coliformes, Enterococcus and Clostridium, as well as bacilli of Salmonella rode. Simultaneously, the necessary tests for determining physical and chemical properties of hams have been made including the determination of the contents of residual nitrites and nitrates, contents of sodium chloride, water content as well pH of meat. Each ham has been treated as an individual testing subject, no results have been averaged. Brine concentration in meat was calculated $BC = \{\%NaCl/(\%NaCl+\%H_2O)\}*100\%$

Results and discussion

- The tested hams have been free from pathogenic bacteria. Moulds at the level of 10^3/ - 10^4/g have occurred in three hams representing various variants of experiment.
- The substantial quantities of aerobic bacteria have been determined at their big differentiation between particular hams (up to 5 orders), with their contents in the outer layer usually higher by 1 order of magnitude.
- The substantial quantities of staphylococci (mostly from the starter culture) have been determined at their big differentiation between particular muscles (up to 7 orders), with their contents in the outer layer usually higher by 1 to 2 orders.
  The appearance of lactic acid bacteria has been irregular to a great extent; they have not appeared in many hams (below the sensitivity threshold of the method), the substantial quantities have, however, been found in heavy hams cured with smaller doses of curing salts.
- The substantial quantities of yeasts (up to 10^7 cells) have been determined. The comparative analysis has shown that in the hams protected against drying with the fat and spicy paste the number of yeast cells has been by about 2 orders higher that in the remaining ones.

From the chemical tests we may conclude that the very big brine concentration (BC) has been determined, especially in small weight hams, which have been substantially hydrated during the process. The weight of hams has also been an important factor differentiating the levels of residual concentration of nitrates and nitrites. The specific non-linear dependence (2) between the total nitrates and nitrites (TN) and after-curing ham weight (W) has been found, which for the variants I, II and III may be fitted with good closeness (r = 0,97) with the equation: $\log TN = 1{,}317 \log D_i - 0{,}337\ W - 0{,}265$ (i = 1,2,3). The statistical correlation analysis has been made and its results presented in the table.

As it may be seen in the table the brine concentration (BC) has a substantial influence on the number of all tested bacteria. Sum of nitrates and nitrites (SA) significantly influences the number of investigated bacteria, not affecting, however, the determined number of yeasts (Y).

Kind of microbes	Physical and chemical parameters							
	Brine concentration (BC)		Total nitrates and nitrites (TN)		Nitrites (N)		pH	
Layer	outer	inner	outer	inner	outer	inner	outer	inner
log (Total Aerobic Count) (AC)	$-0,748^{xx}$	$-0,727^{xx}$	$-0,656^{xx}$	$-0,542^{xx}$	$-0,446^{xx}$	$-0,410^{x}$	$0,449^{xx}$	$0,573^{xx}$
log (Staphylococcus Count) (S)	$-0,742^{xx}$	$-0,749^{xx}$	$-0,811^{xx}$	$-0,830^{xx}$	$-0,393^{x}$	$-0,506^{xx}$	0,266	$0,368^{x}$
log (Lactic Acid Bacteria Count) (LAB)	$-0,679^{xx}$	$-0,515^{xx}$	$-0,500^{xx}$	$-0,397^{x}$	$-0,543^{xx}$	$-0,402^{x}$	$0,553^{xx}$	$0,531^{xx}$
log (Yeasts Count) (Y)	$-0,403^{x}$	$-0,495^{xx}$	-0,160	-0,131	0,001	-0,160	$0,342^{x}$	0,248

xx - substantial at $\alpha = 0,01$ x - substantial at $\alpha = 0,05$

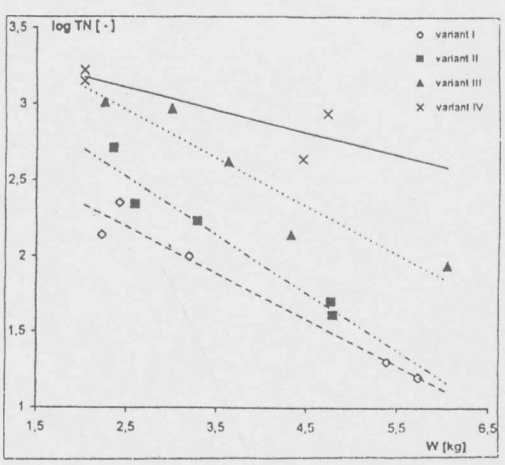
The lower correlation factors achieved in the relations with nitrites only (N) show that the bactericidal or bacteriostatic properties in the crude meat medium are characteristic for nitrites and nitrates. As it might have been expected the pH factor of meat has also a certain influence on its microbiological condition. Taking into consideration that the tested relations concerned the inter-correlated parameters, the analysis of multiple regression has been made and its results have been presented in the main components system for outer layer (Fig. 2, 3, 4, 5). The determined relations may be described with the following formulas:
(values of the multiple correlation factor R_w given in brackets):

for outer layer:

$S = 22,711 - 0,231 * BC - 0,00213 * TN - 2,115 * pH$ (0,892)
$AC = 7,362 - 0,171 * BC - 0,00094 * TN - 0,300 * pH$ (0,794)
$LAB = -11,545 - 0,249 * BC - 0,00080 * TN + 3,178 * pH$ (0,720)
$Y = -2,129 - 0,114 * BC + 1,367 * pH$ (0,425)

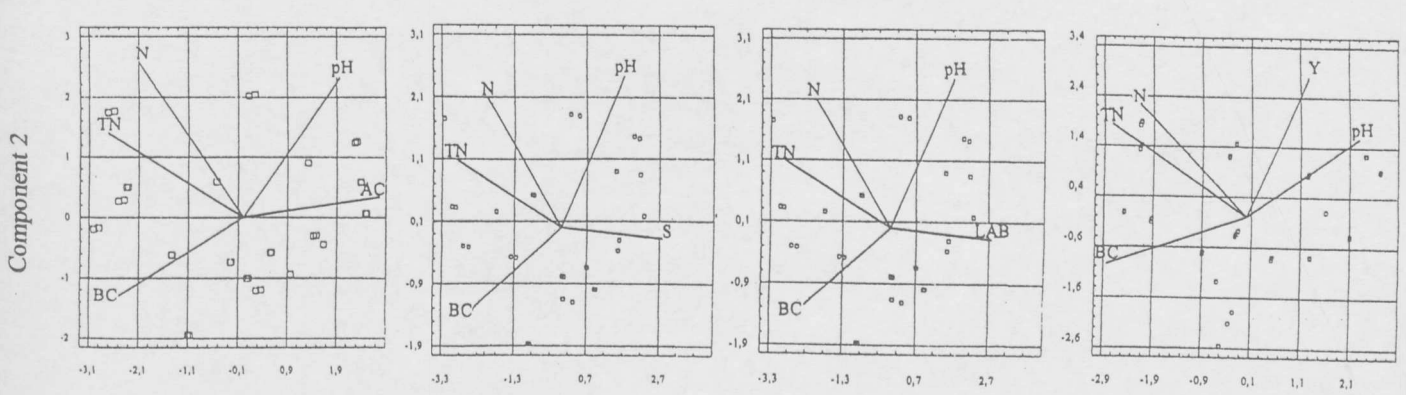
for inner layer:

$S = 12,051 - 0,184 * BC - 0,00216 * TN - 0,676 * pH$ (0,892)
$AC = -1,717 - 0,139 * BC - 0,00046 * TN + 1,536 * pH$ (0,766)
$LAB = -17,172 - 0,097 * BC - 0,00060 * TN - 3,513 * pH$ (0,603)
$Y = 8,438 - 0,160 * BC - 0,364 * pH$ (0,497)



Biplots for variables in multivariate space

Fig.2 Fig.3 Fig.4 Fig.5



Conclusions

1. In the tested dry-cured hams no pathogenic bacteria have been detected.
2. The following substantial kinds of dependence have been determined:
   - Total Aerobic Count in hams on the brine concentration (BC), on the residual concentration of curing substances (TN) and on pH,
   - Staphylococcus Count in hams on the concentration of curing substances (TN) and on the brine concentration (BC),
   - Lactic Acid Bacteria Count in hams on the brine concentration (BC), on pH and on the concentration of curing substances (TN) and they have been described with linear equations.
3. A certain influence of the brine concentration (BC) in hams and their pH on the Yeasts Count has been determined, though the Yeasts Count has also been affected by the application of fat and spicy paste as a drying protection agent.