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# THE EFFECT OF SELECTED TECHNOLOGICAL ADDITIVES ON IMPROVEMENT OF SHELF LIFE OF GROUND MEAT

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**Abstract.** The aim of the study was to investigate the effect of selected technological additives (NaCL, sodium lactate and lactic acid) on shelf life of ground meat. It was found that all the three substances cause reduced microbial growth. Dynamics of action in case of each of these substances vary and depend on their concentrations. A limitation in the feasible amount of applied additives may be their effect on sensory attributes of the product. There is a marked, advantageous interaction of the preserving activity of these substances. Using recorded results it is possible to optimize the composition of the mixture of analysed additives.

**Key words:** minced meat, ground meat, microbiological quality, additives, sodium lactate, lactic acid, microbiological growth, shelf-life

## INTRODUCTION

Recently ready-to-eat meat products and half-products have been gaining in popularity [Lamers 1996]. One of them is ground meat being the basic component of meatballs, batters, hamburgers, etc. Due to its composition, comminution and ready access of air and moisture it is susceptible to microbial contamination [Nassos et al. 1983, Białosiewicz et al. 2002, Elmali and Yaman 2005]. For the sake of consumer safety the total count of mesophilic aerobic bacteria in ground meat should not exceed $10^6$ cells/1 g product [Zalewski 1985, Rozporządzenie... 2002]. One of the factors limiting the adverse storage changes in meat products is the application of different types of additives [Sahoo and Anjaneyulu 1997, Pohlman et al. 2002, Stivarius et al. 2002, Dave 2003, Osterlie and Lerfall 2005, Serdaroğlu 2006].

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In case of ground meat the use of most known preservatives is limited or even prohibited. Positive exceptions in this respect might be lactic acid and its salts. Lactic acid L(+) and its salts are treated as natural components of meat and in food technology lactic acid serves the functions of a regulator of acidity, a preservative and a flavouring, as well as an agent enhancing antioxidant activity of other substances [Ouattara et al. 1996, Uchman 2001, Farag and Korashy 2006]. However, the application of lactic acid to preserve ground meat is difficult from the technological point of view due to the necessity to use very small doses. Much better results may be recorded in case of the application of sodium lactate. The preservative action of sodium lactate has been extensively researched [Shelef 1994, Brewer et al. 1995, Ecert et al. 1997, Sallam and Samejima 2004]. However, in this case the limiting factor is considerably enhanced salty taste in final products produced with an addition of sodium lactate [Ecert et al. 1997, Tan and Shelef 2002].

Analysis of ground meat preservation was a impulse to investigate the concept of the simultaneous application of sodium lactate and lactic acid, and to test their interactions.

The aim of the study was to determine the effect of individual components and of a mixture of sodium chloride, lactic acid and sodium lactate on microbiological stability of ground meat.

## THE EXPERIMENTAL PART

### Experimental material

The following additives were used in the experiments:

1. Sodium chloride (table salt) – a commercially available product.
2. Sodium lactate (60%) from AKWAWIT.
3. Lactic acid (80%) from AKWAWIT.

All these preparations met the requirements of food standards. The range of applications for these additives was established in the course of preliminary investigations.

In order to maintain uniform experimental conditions these additives were always used in the form of aqueous solutions. Concentrations for these solutions were changed so that each time the added amount of the final solution constituted 10% meat weight and contained the assumed amount (e.g. 2% salt in relation to meat weight) of the analyzed additive. Only 10% water was added to control samples (0% additive).

Ground meat samples were produced by grinding pork (always the same element – the best end of neck) in a grinder (Ø 3 mm). The process of sample preparation itself was performed according to the standard used in practice. Ready samples of approx. 100 g were wrapped in greaseproof paper and stored in a refrigerator (approx. 4°C) until analyzed. Microbiological tests to determine total microbial counts were performed according to Polish standard PN-A-82055-6. All recorded results were analyzed statistically. Depending on requirements different calculation procedures were applied [Uchman et al. 1995, Avery et al. 1996].

## DISCUSSION OF RESULTS

Following the aim of the study the preservative action of three substances was investigated, i.e. that of sodium chloride (table salt), sodium lactate and lactic acid. The range of application for these additives was established based on literature data (mostly for other meat products) and preliminary sensory examinations. These assessments showed that the following values should not be exceeded (especially for mixtures):

– for sodium chloride 3%,
– for sodium lactate 3%,
– for lactic acid 0.5%.

Proper tests were divided into three stages (a, b, c), in which:

a) the effect of individual additives was analyzed,
b) the effect of two-component mixtures was analyzed,
c) the effect of a mixture of all the three substances was analyzed.

All these experiments were conducted under identical conditions and applying the same parameters of assessment. In order to facilitate the reliable interpretation of recorded results they were presented after the initial sample contamination was included ($N_t/N_o$), where: $N_t$ – sample contamination after time t, $N_o$ – initial sample contamination (t = 0).

Then we may arrive at a dependence:

$$\frac{N_t}{N_o} = f(t) \quad \text{or} \quad \lg (N_t/N_o) = f(t).$$

Or using the multifactorial regression function:

$$\lg (N_t/N_o) = f(t, c_d),$$

where: $c_d$ – concentration of applied additive (or additives: $c_{d1}$, $c_{d2}$, ...).

Results indicate the preservative action of all the three investigated substances, as each additive caused reduced microbial growth. The effect of the amounts of these additives on the growth dynamics of total microbial count is presented in three successive graphs (Fig. 1, 2, 3).

For a function of $\lg (N_t/N_o) = B \cdot t$ we may determine parameter $T = 1/B$. Values of T define time (days) required for a 10-fold (one order of magnitude) increase in the total microbial count in the analyzed sample. It may be interpreted as in indicator of the effectiveness of the applied additive. It is also possible to directly determine the dependence between the value of T as the dependent variable and the concentration (concentrations) of an additive(-s). $T = f(c_d)$ or $T = f(c_{d\,1}, c_{d2})$. Table 1 presents the effect of concentration of an addition of NaCl on changes in T values.

All the presented data indicate a significant effect of an NaCl addition on the slowing down of microbial growth. However, within the commonly accepted addition range (up to %) this effect was relatively small (a little less than 24 h), which may suggest that it is advisable to search for other, more effective additives. As it was already mentioned, one of them may be sodium lactate. Results of experiments on the effect of the applied concentration of the added sodium lactate on changes in T values are presented in Table 2.

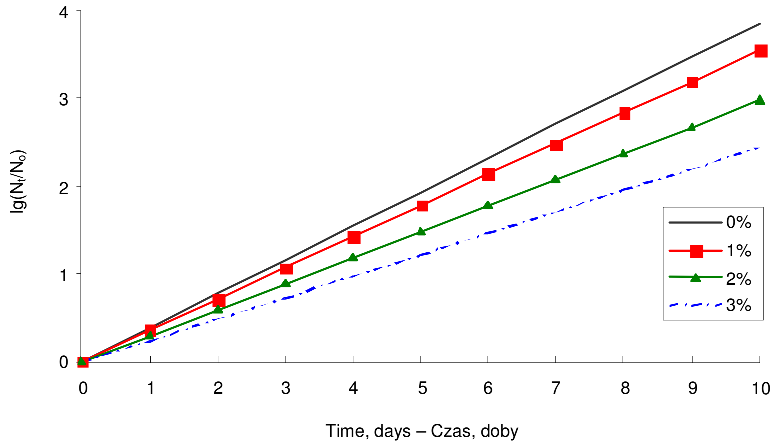


Fig. 1. The effect of a sodium chloride (NaCl) addition on the rate of changes in total microbial count

Rys. 1. Wpływ dodatku chlorku sodu na szybkość zmian ogólnej liczby drobnoustrojów

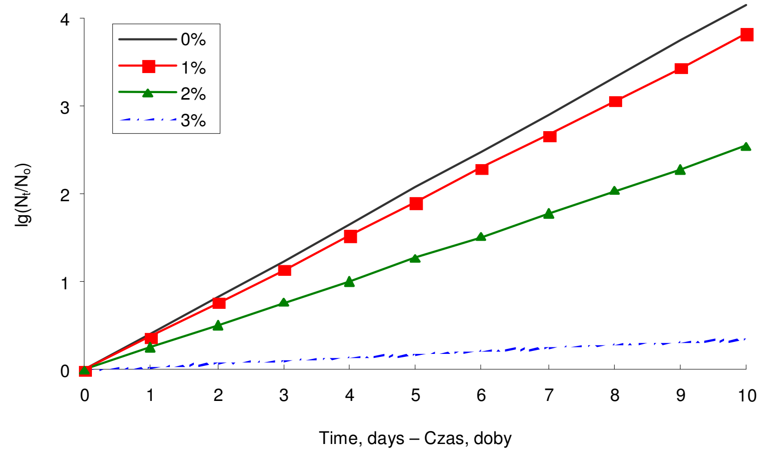


Fig. 2. The effect of a sodium lactate addition on the rate of changes in total microbial count

Rys. 2. Wpływ dodatku mleczanu sodu na szybkość zmian ogólnej liczby drobnoustrojów

The above results confirmed the very significant effect of added sodium lactate on the reduction of microbial growth. This effect is bigger than in case of an addition of NaCl. Results obtained for a 3% addition of lactate are of interest. Both an almost complete inhibition of microbial growth and a lack of statistically significant linear correlation suggest a different character of processes taking place in samples containing this

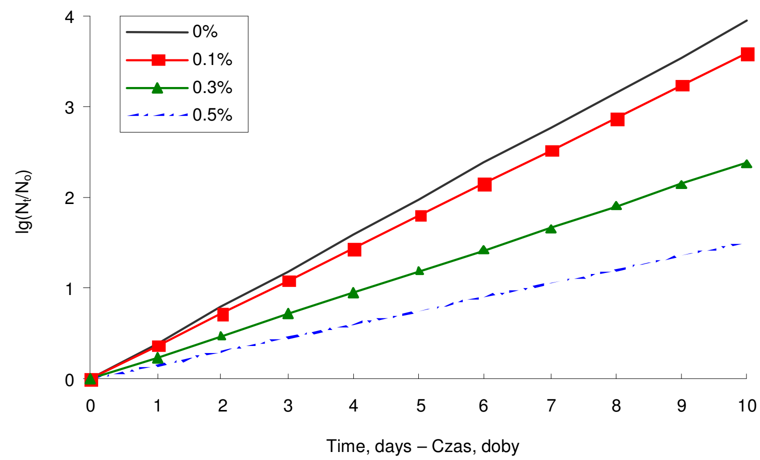


Fig. 3. The effect of a lactic acid addition on the rate of changes in total microbial count
Rys. 3. Wpływ dodatku kwasu mlekowego na szybkość zmian ogólnej liczby drobnoustrojów

Table 1. The effect of a sodium chloride (NaCl) addition on the rate of changes in total microbial count
Tabela 1. Wpływ dodatku NaCl na szybkość zmian ogólnej liczby drobnoustrojów

| Addition of salt<br>%<br>Dodatek soli<br>% | Regression<br>Y = B t<br>Regresja<br>Y = B t | Coefficient of determination<br>$R^2$<br>Współczynnik determinacji<br>$R^2$ | T<br>days<br>T<br>doby |
|---|---|---|---|
| 0 | Y = 0.3868 t | 0.941 | 2.59 |
| 1 | Y = 0.3557 t | 0.946 | 2.81 |
| 2 | Y = 0.2982 t | 0.834 | 3.35 |
| 3 | Y = 0.2453 t | 0.818 | 4.08 |

Table 2. The effect of a sodium lactate addition on the rate of changes in total microbial count
Tabela 2. Wpływ dodatku mleczanu sodu na szybkość zmian ogólnej liczby drobnoustrojów

| Addition of sodium lactate<br>%<br>Dodatek mleczanu sodu<br>% | Regression<br>Y = B t<br>Regresja<br>Y = B t | Coefficient of determination<br>$R^2$<br>Współczynnik determinacji<br>$R^2$ | T<br>days<br>T<br>doby |
|---|---|---|---|
| 0 | Y = 0.4151 t | 0.991 | 2.41 |
| 1 | Y = 0.3826 t | 0.984 | 2.61 |
| 2 | Y = 0.2539 t | 0.971 | 3.94 |
| 3 | Y = 0.0353 t | 0.257 | 28.30 |

additive. A significant correlation could be obtained after the rejection of results recorded in the second day of sample storage. However, in the conducted additional experiments a similar course was always found for changes in microbial counts after the level of a 3% addition was exceeded. Absolute results varied and depended on the initial contamination of the sample. This phenomenon could have been explained only after a considerable extension of the experiments with a simultaneous change of the assumed aim and scope of the study. However, due to the observable changes in the sensory quality of the product (saltiness) it is not advisable to exceed the 2% level of sodium lactate addition. A considerable effect of sodium lactate addition on the enhanced sensation of product saltiness was described in numerous studies [Ecert et al. 1996]. Table 3 presents results of assessment of the effect of lactic acid addition on changes in T values.

Table 3. The effect of a lactic acid addition on the rate of changes in total microbial count
Tabela 3. Wpływ dodatku kwasu mlekowego na szybkość zmian ogólnej liczby drobnoustrojów

| Addition of lactic acid<br>%<br>Dodatek kwasu mlekowego<br>% | Regression<br>Y = B t<br>Regresja<br>Y = B t | Coefficient of determination<br>$R^2$<br>Współczynnik determinacji<br>$R^2$ | T<br>days<br>T<br>doby |
|---|---|---|---|
| 0.0 | Y = 0.3960 t | 0.988 | 2.53 |
| 0.1 | Y = 0.3603 t | 0.967 | 2.78 |
| 0.3 | Y = 0.2381 t | 0.889 | 4.20 |
| 0.5 | Y = 0.1512 t | 0.737 | 6.61 |

The above results confirm the advantageous effect of the addition of lactic acid on microbiological stability of ground meat. This effect becomes even more significant after the 0.1% dose is exceeded. However, we have to take into consideration the possible negative action of the highest tested dose (0.5%) on the quality of final product made from such preserved half-product.

All the results presented above indicate that the effectiveness of these additives varies. Especially sodium lactate deserves special attention. A slight variation may be observed between a 1% and 2% addition of sodium lactate and a rapid increase in effectiveness at the application of a 3% addition. Moreover, increased effectiveness in the action of lactic acid may be observed in the upper range of amounts of applied additives. Within the sensorily acceptable range a positive effect of added lactic acid is only slightly bigger than that of the addition of sodium chloride and similar to that of the sodium lactate addition.

Thus in the next stage of the study it was decided to verify the possible application of a mixture of these substances, since there are premises to believe there is a possible synergistic interaction. All variants of two-component mixtures were tested; however, in this paper results of two systems are presented, i.e.:

1) sodium lactate with sodium chloride,
2) sodium lactate with lactic acid.

In case of assessment of a mixture of sodium lactate and sodium chloride it was established that total microbial count in tested samples of ground meat depended on all analyzed factors, i.e. storage time, the amount of added sodium lactate and sodium chloride addition.

This dependence may be described by the following equation:

$$Y = 4.9439 - 0.1879 \cdot s + 0.3052 \cdot m + 0.4090 \cdot t + 0.02120 \cdot s^2 - 0.18667 \cdot m^2 + \\ - 0.0001459 \cdot t^2 + 0.081797 \cdot s \cdot m - 0.07064 \cdot m \cdot t - 0.03544 \cdot s \cdot t$$

where:

$Y = \lg N_t$
t – storage time, days,
s – addition of sodium chloride, %,
m – addition of sodium lactate, %.

The above dependence exhibits very good representation of experimental results ($R^2 = 0.98$). Thanks to this it is possible to precisely forecast the microbiological condition by supplying respective data to the equation. Thus, e.g. at an addition of s = 2% and m = 1% and storage time t = 3 days the computed value of $\lg N_t$ is 5.74, while when the experimental value is 5.47 ($\Delta = -0.26$). This is an admissible difference, falling within the range of experimental errors. Much better results for the determination of the effect of analyzed additives was obtained after the value of initial contamination of samples was taken into consideration and the value for coefficient T for model mixtures of additives was calculated.

As a result of computational transformations described, above a dependence was obtained between the value of T as a dependent variable and independent variables, s and m.

$$T = 2.392 + 0.3449 \cdot s - 0.1910 \cdot m + 0.05679 \cdot s^2 + 0.4759 \cdot m^2 - 0.008929 \cdot s \cdot m.$$

This dependence is presented graphically in Figure 4.

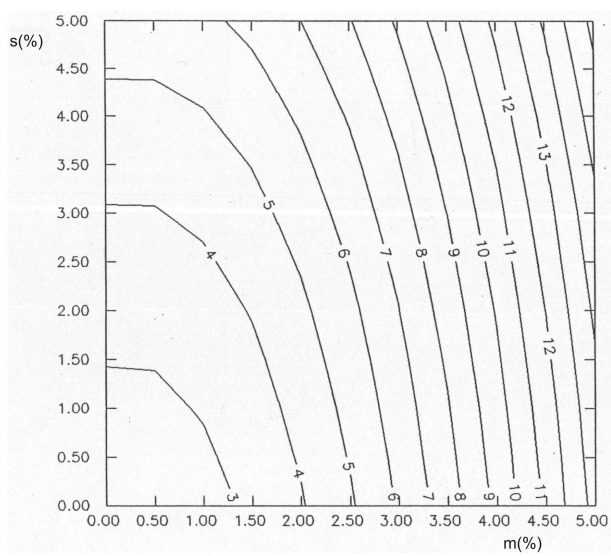


Fig. 4. The value of T-coefficient as a function of the addition of sodium chloride (s) and sodium lactate (m)

Rys. 4. Wartość współczynnika T jako funkcja dodatku chlorku sodu (s) i mleczanu sodu (m)

Also in this Figure we may observe a bigger effect of sodium lactate addition than that for sodium chloride. The presented dependence makes it possible to determine the composition of the mixture of these two substances to obtain the assumed shelf life of ground meat.

Similar analyses were also conducted for mixtures of sodium lactate and lactic acid. When analyzing parameter T the following dependence was obtained:

$$T = 2.4610 - 0.5744 \cdot m + 0.2932 \cdot k + 0.6765 \cdot m^2 + 18.1136 \cdot k^2 + 7.4386 \cdot m \cdot k.$$

This dependence is significant at $\alpha = 0.05$ and its graphic form is given in Figure 5.

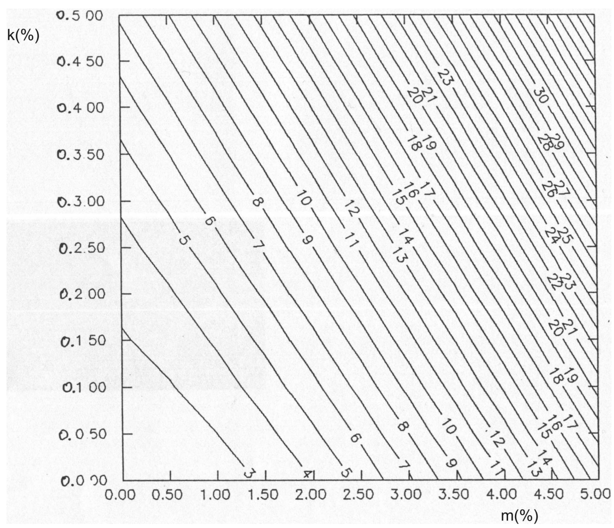


Fig. 5. The value of T-coefficient as a function of the addition of sodium lactate (m) and lactic acid (k)

Rys. 5. Wartości współczynnika T jako funkcja dodatku mleczanu sodu i kwasu mlekowego

The presented dependence is an increasing function, which means that each increase in the amounts of both analyzed components in the mixture results in an increased value of coefficient T. In the next stage of the study mixtures of all the three investigated additives were tested. Results made it possible to determine the dependence of value $Y = \lg N_t$ on the amount of applied additives and storage time of samples. It is statistically significant ($\alpha = 0.05$), although due to the number of variables it may not be presented graphically in a simple form. To facilitate the interpretation of the results, values of coefficient T were calculated and they are presented in the Table below.

In case of three independent variables nine test points are not enough to obtain the complete Taylor expansion. Thus calculations of the dependence of T values on the amounts of additives were divided into stages. Initially a simple dependence was established (the first order) $T = f(s, m, k)$ and the following equation was obtained:

$$T = 0.8198 + 0.5568 \cdot s + 2.1293 \cdot m + 15.4398 \cdot k.$$

Table 4. The effect of an addition of sodium chloride, sodium lactate and lactic acid on the rate of changes in total microbial counts

Tabela 4. Wpływ dodatku chlorku sodu, mleczanu sodu i kwasu mlekowego na szybkość zmian ogólnej liczby drobnoustrojów

| No. | Variant of calculations<br>Wariant obliczeń | | | Value T<br>days<br>Wartość T<br>doby |
|---|---|---|---|---|
| | s, % | m, % | k, % | |
| 1 | 0.0 | 0.0 | 0.0 | 2.37 |
| 2 | 2.0 | 0.0 | 0.0 | 3.21 |
| 3 | 0.0 | 2.0 | 0.0 | 3.82 |
| 4 | 0.0 | 0.0 | 0.3 | 4.17 |
| 5 | 1.0 | 1.0 | 0.1 | 3.56 |
| 6 | 2.0 | 1.0 | 0.2 | 5.55 |
| 7 | 1.0 | 2.0 | 0.3 | 12.53 |
| 8 | 2.0 | 2.0 | 0.1 | 7.07 |
| 9 | 1.0 | 2.0 | 0.2 | 9.93 |

The calculated $R^2$ was 0.797, which already ensures a high level of confidence ($\alpha$ = 0.035). This makes it possible to use this equation to forecast the T value. A more detailed analysis of calculations shows varied significance of individual components and thus the content of salt is significant at $\alpha_s = 0.52$, while that of lactate at $\alpha_m = 0.022$ and that of lactic acid at $\alpha_k = 0.031$. This means that from the mathematical point of view in this forecast we may omit the addition of sodium chloride and the above linear equation takes the form:

$$T = 1.299 + 2.1230 \cdot m + 15.3236 \cdot k.$$

In this case we obtain $R^2 = 0.778$ and $\alpha = 0.011$.

A similar procedure may be performed taking into consideration successive elements of the Taylor series in order to obtain the necessary number of degrees of freedom. Although we will not obtain in this way the complete expansion, still we may arrive at an approximation perfectly sufficient for practical purposes.

As a result of these calculations the following equation was put forth:

$$T = 2.1791 + 0.2494 \cdot s + 0.4733 \cdot m^2 + 20.2524 \cdot k^2 + 10.7760 \cdot m \cdot k.$$

It exhibits high accuracy ($R^2 = 0.985$) and makes it possible to include the presence of all applied additives in further calculations. Thus e.g. when we substitute s = 2%, m = 2% and k = 0.1% we obtain T = 6.93, while the experimental value given in Table 4 is 7.07 ($\Delta$ = 0.14; app. 3-4 hours). This is very good consistency. In case when the amount of one of the additives is assumed as constant, the above equation may be presented in the graphic form. For example we may assume that sodium chloride content in meat products is usually 2%. Calculations may then be simplified. However, thanks to the found interaction of all additives it is possible to reduce NaCl content.

Results presented above indicate it is advisable to use a mixture of all the three analysed substances. In such a case meat shelf life is considerably extended in comparison to the separate application of corresponding amounts of individual components. Obviously the possible synergistic action of these substances also on sensorily examined product quality attributes remains an open issue.

## CONCLUSIONS

1. All the three analyzed substances (NaCl, sodium lactate and lactic acid) cause reduced microbial growth.

2. Dynamics of the action of each substance vary and depend on their concentration. These dependencies may be described in the form of mathematical functions with a high level of statistical significance.

3. There is a distinct interaction of the preservative action of these substances and this action in the mixture is more effective than the action of individual substances separately.

4. Using presented results it is possible to optimize the composition of the mixture of analyzed additives.

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## WPŁYW WYBRANYCH DODATKÓW TECHNOLOGICZNYCH NA POPRAWĘ TRWAŁOŚCI MIĘSA MIELONEGO

**Streszczenie.** Celem pracy było zbadanie wpływu wybranych dodatków technologicznych (NaCL, mleczan sodu i kwas mlekowy) na trwałość mięsa mielonego. Stwierdzono, że wszystkie trzy substancje wpływają na zwolnienie namnażania się mikroflory. Dynamika oddziaływania każdej z tych substancji jest różna i zależy od ich stężenia. Ograniczeniem w ilości zastosowanych dodatków może być ich oddziaływanie na właściwości sensoryczne wyrobu. Występuje wyraźna, korzystna interakcja wzajemnego oddziaływania utrwalającego tych substancji. Przedstawione wyniki można wykorzystać do optymalizacji składu mieszaniny badanych dodatków.

**Słowa kluczowe:** mięso mielone, jakość mikrobiologiczna, dodatki, mleczan sodu, kwas mlekowy, trwałość

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