RELATIONSHIPS BETWEEN WATER ACTIVITY AND CERTAIN OTHER PHYSICO-CHEMICAL PROPERTIES OF BULGARIAN RAW-DRIED SAUSAGE PREPARED WITH SELETCED MICROCOCCAL STARTER CULTURES

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SUMMARY

The relationships between water activity (a_w) and fermentation period, pH, dry matter, colour characteristics, total protein and fat of the Bulgarian raw-dried sausage 'lukanka' prepared with different micrococcal starter cultures have been investigated.

A model regression equation ($Y_i = a + b.x_i$) has been suggested for adequately depicting the influences of the fermentation period, pH, dry matter, weight loss, and colour characteristics of the sausage on its a_w-values. The total protein and fat did not have any correlation with the a_w. A very high multiple linear regression coefficient between a_w, pH, dry matter, and colour characteristics have been established which enables prediction of the a_w-values.

The possibility of predicting the weight loss of the sausages (Δ_m) during the fermentation process (t) through the use of the model $\Delta m = \Delta m_k(1 - e^{-k_1 t})$ has been investigated.

Similarly, attempts were made to record the dry matter content (Q) of the raw-dried sausages depending on the period of fermentation (t) with the linear regression model: $Q = Q_o + B.e^{-k_2 |t}$.

INTRODUCTION

Production of raw-dried sausage is a very complex process. Particularly during the process of ripening, the sausage mix undergoes complex biochemical and physical changes. Normally, these changes are monitored by determining the a_w, pH, and other

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such quality indicating parameters of the sausage. Hence, it is of importance to investigate the correlations among these parameters so as to enable prediction of a particular index with the help of other available indices.

In this study, an attempt was made to determine the correlations between a_w -values and certain other physico-chemical properties of Bulgarian raw-dried sausage 'lukanka' prepared with different micrococcal starter cultures and also to study the kinetics of the drying process to help prediction of the state of ripening at any given period on the production process.

MATERIALS AND METHODS

The composition and the typical processing conditions of the sausage were described in our earlier report (Borpuzari and Boschkova, 1993). Pure micrococcal starter cultures of *Micrococcus varians* M160 and M483 isolated from 'lukanka' were inoculated into the filling mass at the level of 10^7 cfu/g. A control batch without the addition of starter culture was prepared simultaneously under similar processing conditions. The physico-chemical properties of the sausages during different stages of production, namely, the sausage mix, 24h after the initial fermentation period, 3rd, 6th, 13th day of ripening and the finished products were determined as per methods outlined below:

Water activity (a_w): Water activity values were determined by the automatic a_w-meter (Model EEJ 3; Novasina Ltd., Zurich, Switzerland).

pH: pH was determined by a pH meter equipped with combination electrode and thermometer (Model MS 2004, Microsyst, Bulgaria).

Dry matter: Dry matter was determined as per the AOAC (1970) method.

Weight loss: The weight loss of the sausages during different stages of the production process was calculated on the basis of the initial weight and expressed as % weight loss.

Colour characteristics: Colour characteristics of the sausage (red colour component, a^*) was determined in the spectrophotometer (PYE Unicam PU 8800 uv/vis, Philips) as per the CIE Lab method (Iudd and Wyszecki, 1975).

Total protein : Total protein was determined as per classical method of Kjeldahl (1883) in Kjeltec Auto 1030 Analyser (Tecator, Hoganas, Sweden).

Total fat : Total fat was determined as per the classical method of Soxhlet by diethyl ether extraction.

Statistical analysis of the experimental data for determining the linear regression coefficients among the different variables was performed as per least-square method (LSM) described by Brandt (1970). Analysis of the LSM for the simple linear regression was performed through the computer programme LIN compiled by Johnson (1980). And the multiple regression analysis of the data was done through the computer programme MLRG of the IBM (1970).

Analysis of the data for defining the non-linear regression equation was performed as per method of Johnson (1980) through the computer programme NONLIN.

All the abovementioned computer programmes were in the form of FORTRAN 77 of the PC "Pravetz 16", Bulgaria.

RESULTS AND DISCUSSION

Correlations between a_w and other physico-chemical properties like the time of ripening (t), pH, dry matter, weight loss, colour characteristics (a^*), total protein and fat were determined on 3 batches of lukanka produced by using micrococcal starter cultures (strains M160 and M483) together with a simultaneous control batch.

Linear regression coefficients between the a_w and the abovementioned physico-chemical properties of the sausage was calculated with the help of the equation,

$$Y = a + b.x_i \qquad \text{... ... ... (1)}$$

where, $Y = a_w$ and x_i = the different physico-chemical properties of the sausage.

Results of the regression analysis of the data on the influence of t, pH, dry matter, weight loss, and colour characteristics (a^*) on the a_w-values are presented in Table 1 to 5, respectively.

From the results (Table 1) it is seen that with the advancement of the ripening process there was a decrease in the a_w-values of all the 3 groups of sausages and the rate of changes was more pronounced in case of sausage produced with the strain M160 and the least in the control sample. Very high coefficients of correlations ($R > 0.96$) were found for all the 3 groups of sausages indicating that a_w-values of the sausages can be predicted with high accuracy at any time of the ripening process if other production conditions are controlled.

Changes in the pH values were highly correlated with the changes in the a_w-values and in all the 3 groups of sausages very high coefficients of correlations ($R > 0.85$) were found which was, however, more pronounced in case of the control samples

(Table 2).

Similarly, changes in the dry matter content of the sausages were highly correlated with the changes in their a_w-values - with the increase in the dry matter content there was a decrease in the a_w-values. This correlation was highly evident in case of control samples and the least in sausages prepared with the strain M483 (Table 3).

Very high coefficient of correlation ($R > 0.98$) was found between the a_w and the weight loss of the sausages (Table 4). The rate of change of the a_w-values was highly pronounced in sausages prepared with M160 and the least in the control samples. Drehsen *et al.* (1993) also observed linear regression correlations between a_w and weight loss of sausages during the process of ripening.

There found to exist correlations between the changes in the colour characteristics - red colour component (a^*) of the sausages and the a_w-values (Table 5) which was, however, somewhat weakly expressed ($0.6 < R < 0.76$) as compared to the correlations of the a_w with the abovementioned other physico-chemical characteristics.

Analysis of the data on the influence of total protein and fat on the aw values of the sausages did not show good correlation and the coefficients of correlations was less than 0.3.

From the practical point of view it is of importance to determine the multiple regression coefficient between the a_w and t, pH and colour characteristics (a^*) of the sausages. In our case, the multiple linear regression coefficients of the above parameters was determined by the equation,

$$a_w = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \quad \dots\dots\dots (2)$$

where, β_i, is the regression coefficients ($i = 0,1,2,3$) of the multiple linear correlation. Data were analysed by the LSM of the computer programme MLRG. Definite values of the multiple regression coefficients (R_M) of the equation (2) for different groups of sausages are presented in Table 6.

From the results it is seen that the changes in the a_w-values of sausages in all the 3 groups were highly influenced by the changes in the t,pH, and colour characteristics (a^*) of the sausages ($R_M > 0.99$).

From the above discussion of the results, it is seen that the changes in the weight loss and the dry matter content of the sausages were highly correlated with the changes in their a_w-values. Therefore, it was of interest to study the influence of the micrococcal starter cultures on the kinetics of weight loss and dry matter content of lukanka. For the purpose, we have calculated the kinetics of weight loss in lukanka during different stages of its production as follows:

If Δm is taken as weight loss of sausage as a result of moisture loss within the period of time (t), then at the final stage of drying after a long period, weight loss will be Δm_k. The process of weight loss will be accomplished by the rate of constant k_1 as per the equation,

$$\Delta m = \Delta m_k(1 - e^{-k_1 t}) \qquad \text{... ... ... (3)}$$

Applicability of the equation (3) for recording the weight loss of sausages was tested on raw-dried sausage lukanka prepared with the micrococcal strains and the control samples. Analysis of the data for determining the Δm_k and k_1 was performed with the computer programme NONLIN as per method of Newton and Raphson described by Johnson (1980).

Results of the analysis of the data on the kinetics of weight loss are presented in Table 7. From the results it is seen that as compared to the treated samples k_1 was much smaller in the control samples which had comparatively less weight loss (Δm_k) at the end of the ripening process. k_1 was highest in case of samples prepared with the strain M160 but the weight loss was lesser at the end of the ripening process as compared to samples prepared with M483 which may probably be due to better removal of moisture. The values of Δm_k and k_1 for all the 3 groups of sausages indicated that the equation (3) may successfully be used in predicting the weight loss of sausages at a given period of time under specific conditions of production or storage which may be of practical importance in the trade of such meat products.

For determining the changes in the dry matter content of the sausages at a given period of time, let us suppose that in the begining of the ripening process, t = 0, the quantity of the dry matter in the sausages will be Q_o. After a prolonged period, t, which is in our case ∞, we may assume that the maximum quantity of dry matter in the samples will be Q_{max}. Therefore, the changes in the dry matter content Q(t) for a given period of time (t) may be calculated with the following equation,

$$Q(t) = Q_o + B.e^{-k_2/t} \qquad \text{... ... ... (4)}$$

where, k_2 = the rate of increase in the quantity of dry matter in the sausage, t = period of time (d) and B = the quantity of dry matter added to the initial value Q_o for obtaining Q_{max} at t = ∞.

With the help of the LSM, the values of B and k_2 were determined through the computer programme LIN and the results are presented in Table 8.

From the results presented in Table 8, values of the equation (4) may be obtained and the quantity of the dry matter content of the sausages can be predicted for any given period of time during the process of ripening of the sausages.

CONCLUSION

The water activity values of the sausages are influenced by the period of ripening, pH, dry matter content, weight loss, and colour characteristics. A model regression equation has been suggested for depicting the influences of these physico-chemical parameters on the a_w-values of the sausages.With the suggested mathematical models the kinetics of weight loss and the changes in the dry matter content of the sausages may be predicted accurately which may be of importance in the processing of such meat products.

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