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THE INFLUENCE OF TEMPERATURE ON SOME PARAMETERS FOR DRY SAUSAGE DURING RIPENING

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SUMMARY

There are several processing parameters which are important for the production of good quality dry sausage. One of these is ripening temperature. In this study ripening temperatures of 15, 20, 25 and 30°C for zervelat sausage in 60 mm calibre casings, and using starter culture, were compared by measurement of pH, firmness, water activity, water content and weight loss during a 28-day period.

The results of the study showed that temperature of ripening directly influences the rate of development of firmness and pH fall in the dry sausage. The velocity of ripening increased with ripening temperature so that a 5 Celsius degree increase in temperature approximately doubled the rate. The firmness increased as the pH dropped below 5·4. Water activity decreased continuously, the rate increasing as the ripening temperature was increased. Water content behaved similarly. At the lowest ripening temperature (15°C) the pH did not drop below 5·2. Higher ripening temperatures resulted in a slightly higher ultimate firmness of the dry sausage.

INTRODUCTION

Centuries of development in the art of salting, dehydration and acidification through natural fermentation of uncooked meat has resulted in a large assortment

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of tasty, good quality sausages in Europe. Emigrants have brought these time-proven processes to the 'New World'. Until quite recently, the old methods of preparation had not changed appreciably. However, in the past few decades, a supermarket-based food distribution system in Australia has exposed many of these ethnic commodities to the majority of the population.

In order to supply the resulting demand, some manufacturers have modified existing methods or introduced new methods to the manufacture of fermented sausage, which have been described by Kramlich (1971) as an 'art' and have traditionally been practised by only a few specialists.

This reaction to a commercial need has not always been accompanied by adequate consideration of quality for each individual product and has resulted in production failures such as the development of off flavours, unsatisfactory colour development and soft textured products. There are many ways of fermenting and drying (ripening) the large variety of dry sausage types. As reported by Klettner & Rodel (1978), optimal results are obtained by the use of objective test parameters which can be used to monitor the individual process control parameters and hence the desired quality of the dry sausage. Wirth *et al.* (1975) and Klettner & Rodel (1978) have concluded that the important process control parameters during the ripening of dry sausage were temperature, relative humidity and air velocity.

Acton *et al.* (1972) suggested that the fermentation of summer sausage at 22 °C, 30 °C or 37 °C did not significantly affect the product flavour although less acid was produced at 22 °C than at 30 °C or 37 °C. Coretti (1971) stated that temperature has a considerable influence on the fermentation process and that the ripening temperature directly influences the ripening time.

In this study, the term 'ripening' refers to all the chemical, physical, microbiological and enzymic changes taking place in the sausage which are temperature and humidity controlled.

To the present, very little has been reported in the form of comparative studies indicating the influence of different temperatures on test parameters which can be used for monitoring and controlling the ripening of dry sausage products. The aim of this study was to determine the changes in the objective test parameters of a typical zervelat sausage, using a model system. Measurements of pH, firmness, water activity (a_w), moisture content and percentage weight loss were made.

MATERIALS AND METHODS

A 36-kg batch of sausage mix was made with the following formulation: one-third lean beef, one-third lean pork, one-third pork back fat.

For each kilogramme of product, the following ingredients were added: 30 g of nitrite-containing salt. (This curing salt contains 0·5% sodium nitrite; for this

formulation 150 ppm of nitrite was added.) 6 g of glucose, 3 g of ground white pepper, 0·5 g of sodium ascorbate, 0·3 g of fresh garlic and 0·5 g of freeze-dried 'duploferment' starter culture (R. Muller and Co.)

The starter culture was prepared by dispersing the lyophilised culture in a small volume of water and incubating it at 25 °C for 24 h in order to ensure activation of the starter culture whilst maintaining the appropriate ratio of lactobacilli and non-pathogenic staphylococci.

The meat and fresh fat were pre-cut into small pieces and frozen on trays at −18 °C. The process was commenced when the frozen meat was initially chopped in a Kramer Grebe Cutter. The ingredients—curing salt, glucose, ascorbate, pepper, garlic and starter culture—were then added, together with the frozen fat pieces, and the mixture was cut to the desired particle size of a zervelat sausage. The mixture was filled into 'Naturin' R2 60 mm casings (Naturin-Werk Becker and Co.). The filling temperature was −3 °C to −4 °C.

All the sausages were initially placed into one ripening room (H. Maurer and Sohne KG, Germany). The sausages were air dried at 15 °C whilst allowing the individual sausages to equilibrate in temperature in order to minimise condensation. The individual sausages were then placed into individual ripening rooms at 15 °C, 20 °C, 25 °C and 30 °C. The relative humidity was held at 90 % for the first week, then reduced to 88 % for the second week and 80 % for the final two weeks. When active fermentation was completed, as indicated by a pH of about 4·8, the product was transferred to another ripening chamber at 15 °C and the relative humidity shown in Fig. 1.

The pH and water activity selected for the end point of active fermentation were based upon previous experience associated with the manufacture of good quality zervelat sausage (Rodel & Klettner, 1978).

The sausage from the 30 °C ripening room was transferred to the 15 °C drying room after 4 days; from the 25 °C ripening room at 7 days and from the 20 °C ripening room at 14 days. Samples were taken after 1, 2, 3, 7, 10, 14, 21 and 28 days. The following tests were carried out with samples from the 'kernel zone' of the sausage as described by Klettner & Rodel (1978) for 55 mm calibre casings. The percentage weight loss was monitored at each temperature throughout the experimental period. Moisture content was determined using the ISO recommended method, ISO/R 1442-1970. Water activity was determined using an a_w meter produced by the ISO Company, Basel, Switzerland, taking measurements in the kernel zone of the sausage. The pH was measured with a digital readout pH meter (Knick, Berlin, Federal Republic of Germany) taking four readings directly in the kernel zone of the sausage.

Firmness was measured using an Instron 1140 texture meter. The pressure firmness was measured using a cylindrical sample of 12·6 mm diameter and 10 mm high taken from the kernel zone of the sausage. These sausage discs were compressed to 2·6 mm at 20 °C which is 74 % compression of the sample. The drive speed of the

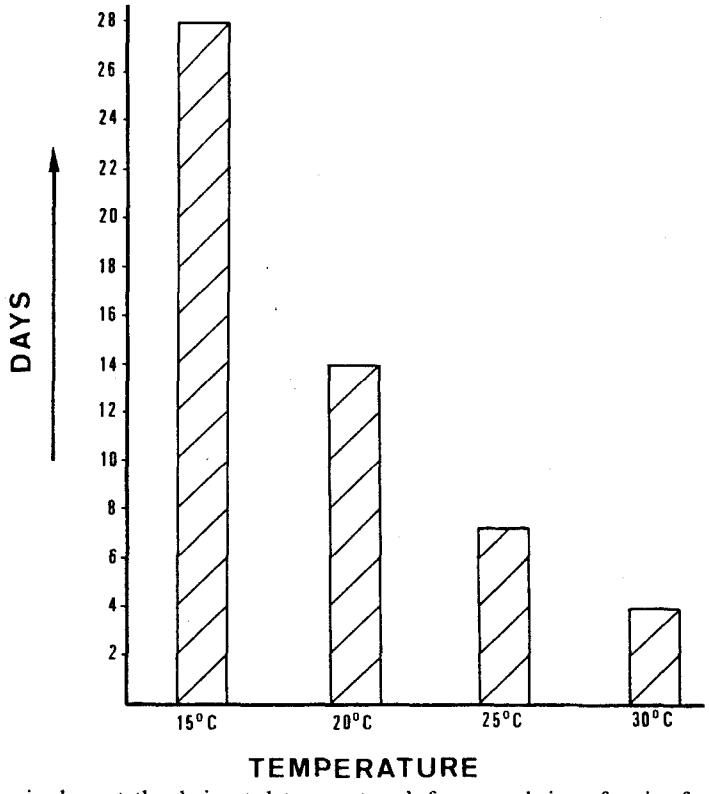

Fig. 1. Time in days at the designated temperature before completion of active fermentation as indicated by a pH of about 4·8. Samples were then held at 15°C at the appropriate humidity.

compression anvil was 100 mm/min. The results were expressed as newtons, as described by Klettner & Rodel (1978).

The protein content of the original mixture was determined by Kjeldahl (total nitrogen $\times 6{\cdot}25$). Fat content was determined using a Soxhlet method (German standard: DIN-Entwurf 10,143, 1971).

RESULTS

The sausage mixture at the commencement of the trial contained 13·9% protein, 33% fat, 3·5% ash and 49·5% moisture, with a pH of 5·78 and a water activity of 0·955.

pH (*Fig. 2*)

In all cases the pH decreased during the first few days of the experiment. At the

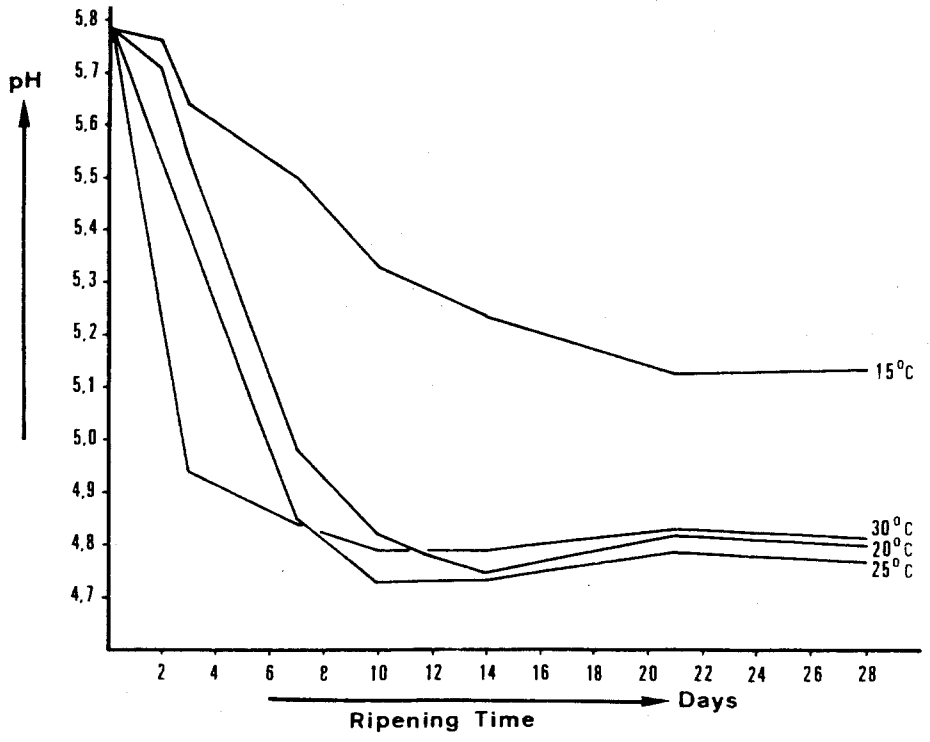

Fig. 2. The influence of temperature on pH during ripening time.

15 °C fermentation temperature, the pH decreased slowly and continued to decrease slowly so that, after 3 days, it was 5·6, after 10 days, 5·3 and after 21 days, 5·1. There was no change after 21 days.

At a temperature of 20 °C the rate of pH decrease was faster than that for the 15 °C fermentation temperature so that, after 3 days, the pH value was 5·5 and, after 10 days, 4·8. From 10 to 28 days there was very little change in pH.

At a temperature of 25 °C the pH value fell more rapidly than at 15 °C and 20 °C so that, on the third day, the pH value was 5·5 and, after 10 days, 4·7. After this time the pH showed a tendency to increase slightly.

At a fermentation temperature of 30 °C, the pH value fell to 4·9 within 3 days and the sample was changed to a ripening room at 15 °C. After 10 days the pH value decreased to 4·8. For the remainder of the experimental period the pH value was nearly constant.

In all cases there was a significant increase in firmness when the pH dropped below 5·4. This occurred at 9 days for a ripening temperature of 15 °C; at 20 °C this pH value was reached in 4 days, at 25 °C after 3 days and at a ripening temperature of 30 °C 2 days were required.

These results indicate that the fermentation velocity nearly doubled for an approximate increase of 5 Celsius degrees in the temperature range of this experiment when starter cultures were used.

Firmness (*Fig. 3*)

The firmness in the centre of the sausage increased with ripening time. At a fermentation temperature of 15 °C there was only a small increase in firmness until the tenth day to 12 N. After this time there was a more rapid increase to 43 N and, after 21 days, a continuing but slow rate of increase to 49 N at 28 days.

At a fermentation temperature of 25 °C, firmness reached a value of 20 N after 3 days and 40 N within 10 days and continued to rise to a value of 74 N after 28 days.

At a ripening temperature of 30 °C, firmness increased very quickly, reading 34 N

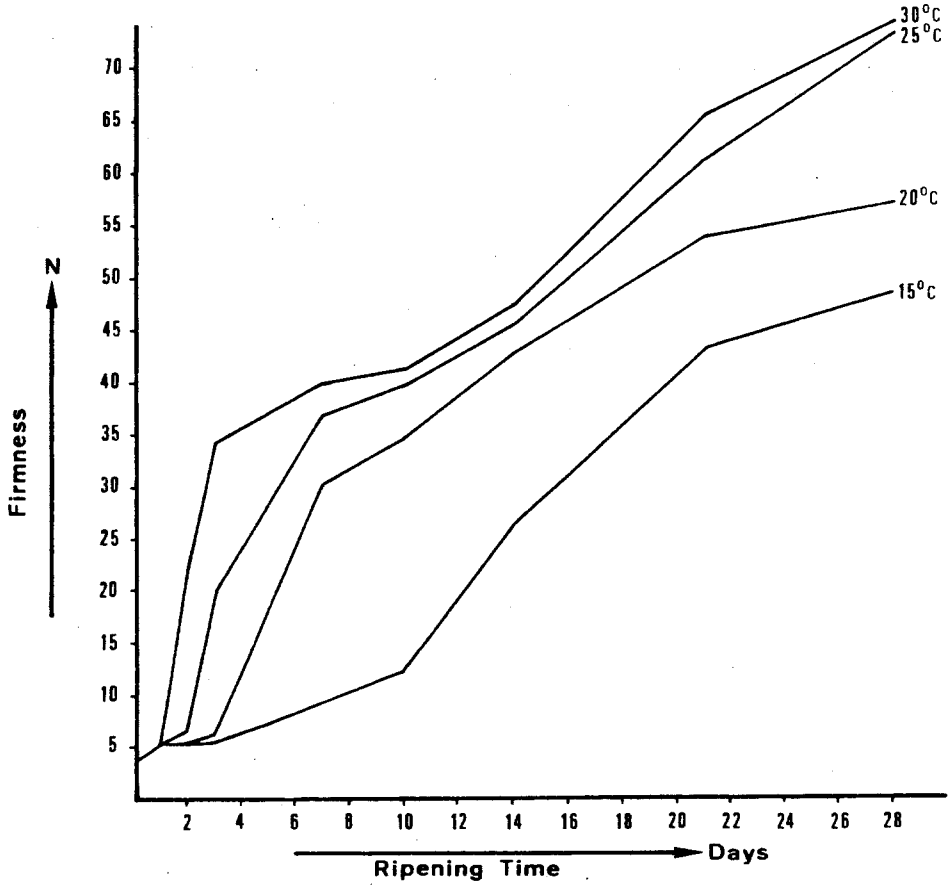

Fig. 3. The influence of temperature on firmness during ripening time.

after 3 days and 41 N after 10 days, rising to a final value of 74 N and exhibiting a similar rate of increase in firmness to the 25 °C fermentation temperature sample.

Water activity (a_w) (*Fig. 4*)

During the ripening time the water activity in the kernel zone of all sausage samples decreased slowly for the first 3 days so that, for the 15 °C sample, there were values of 0·937 after 10 days and 0·896 after 21 days with a continuing decrease to 28 days.

At a temperature of 20 °C there was little difference for the rate of decrease of water activity compared with the 15 °C sample. At a temperature of 25 °C the rate of decrease of water activity was more rapid than at 15 °C and 20 °C so that, after 10 days, the water activity was 0·930 and, after 21 days, 0·883, dropping to a final value of 0·842 after 28 days.

At a fermentation temperature of 30 °C the initial rate of decline of a_w was most rapid, dropping to 0·938 after 3 days and 0·923 after 10 days. From 14 to 28 days the values for 25 °C and 10 °C fermentation temperature samples were similar.

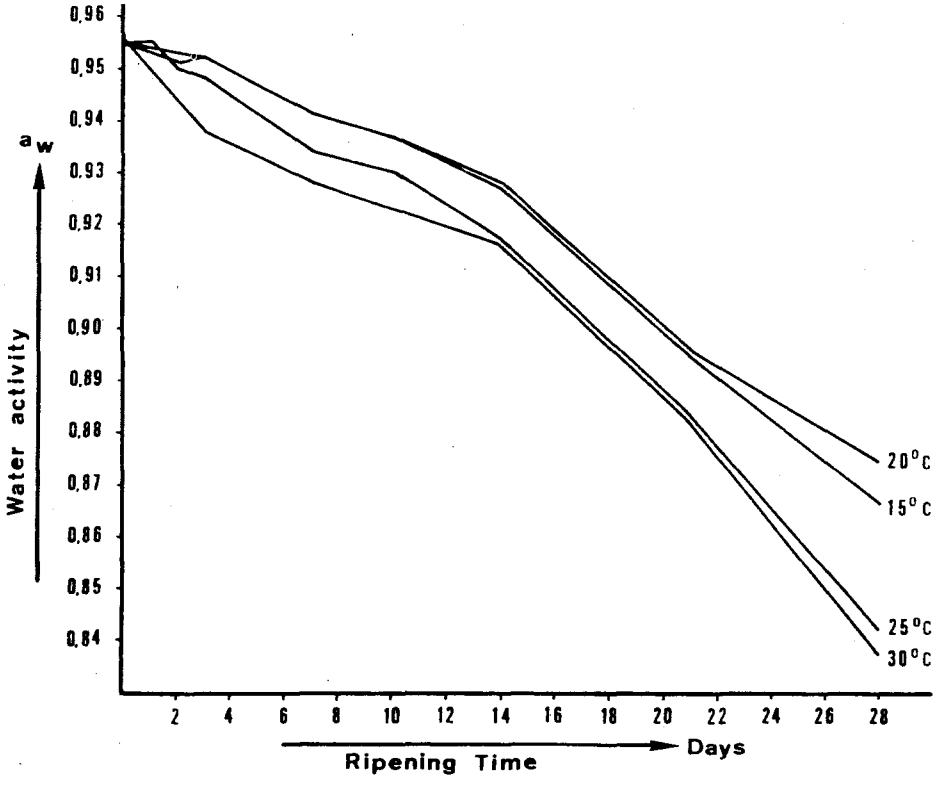

Fig. 4. The influence of temperature on water activity (a_w) during ripening time.

Moisture content (*Fig. 5*)

In all cases the moisture content decreased during the ripening period from an initial value of 49·5 %. At ripening temperatures of 15 °C and 20 °C there was very little difference in the moisture contents of the products from the ripening rooms. The moisture content of the centre of the sausage after 10 days was 45·3 %, decreasing to 36 % after 28 days.

At temperatures of 25 °C and 30 °C the moisture content was reduced to 43·5 %; after 28 days it was 30·8 %.

There was a significant difference in the moisture content of the 20 °C and 25 °C ripened sausages after 4 days. This difference was maintained throughout the study. After 28 days the weight loss at the 15 °C ripening temperature was 28·1 %. The weight losses for both samples from the 25 °C and 30 °C ripening temperatures were 29·4 %. It should be noted that there was a small amount of fat liquefaction from the surface of the sausage at a temperature of 30 °C.

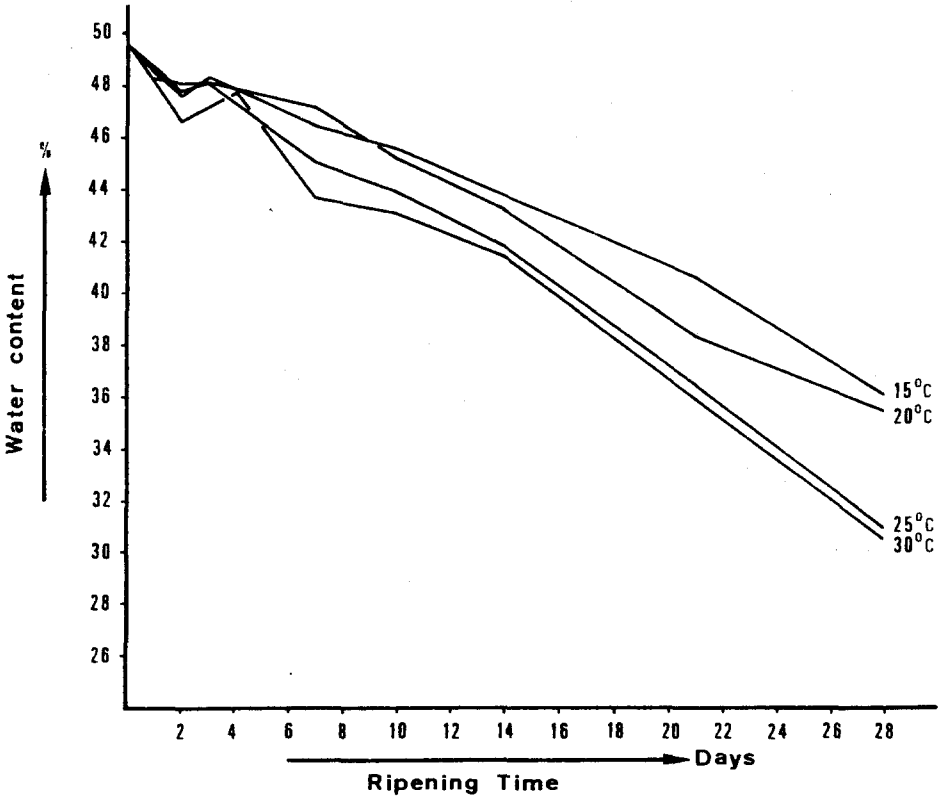

Fig. 5. The influence of temperature on moisture content during ripening time.

TABLE 1
CORRELATION COEFFICIENTS BETWEEN THE MEASURED PARAMETERS AT THE VARIOUS RIPENING TEMPERATURES

	pH	*Firmness*	a_w	*Water*
pH	—	−0·8787	0·6120	0·6963
Firmness	−0·8787	—	−0·8963	−0·9135
a_w	0·6120	−0·8963	—	0·9895
% water	0·6963	−0·9135	0·9895	—

All the values are highly significant at the 0·1 % level, $n = 32$.

At the four different ripening temperatures the calculated correlation coefficients were highly significant (Table 1). The highest correlation coefficient, $r = +0{\cdot}9895$, was found between water activity and water content. The next highest was between water content and firmness ($r = -0{\cdot}9135$), followed by the correlation coefficients between water activity and firmness, $r = -0{\cdot}8963$, and pH and firmness, $r = -0{\cdot}8787$. The lowest correlations occurred between pH and water content ($r = 0{\cdot}6963$) and pH and water activity ($r = 0{\cdot}6120$).

DISCUSSION

The correlations between the parameters were taken from a ripening period of four weeks. The highest positive correlation existed between water activity and water content. Normally this relationship is expressed in the sorption isotherm of the food product. In this case the correlation coefficient relates only to the top portion of the sorption isotherm where it is generally a straight line. The lowest correlations were found between pH and water content and pH and water activity.

The low positive correlations between pH and water content and pH and water activity were to be expected because of the continuous slow decline of water content and water activity throughout the experiment, whilst the pH declines rapidly at the beginning of the process and then remains relatively constant.

Negative correlation coefficients occurred with all parameters and firmness. As the firmness increased, the other parameters decreased. The correlations between firmness and water content and water activity and pH were high (Table 1) and this resulted in a significant influence of the three parameters on firmness, as shown in Table 1. There was a high negative correlation between firmness and water activity. After two weeks firmness was greatly influenced by the decline in water activity (Figs. 3 and 4). The correlation between firmness and water content was a little higher because the loss in water content began earlier in the process and was greater than that of water activity. Firmness increased in proportion to the decline in water content.

These high correlations emphasised the importance of the inter-relationships of

the objective parameters measured and the fact that they could give a measure of the final quality of the dry sausage.

The greatest deviation in the results occurred at a temperature of 15 °C. At the highest ripening temperature of 30 °C an additional factor would be the potential public health risk associated with the growth and toxin production of *Staphylococcus aureus* which will influence the use of this temperature in commercial practice (Hechelmann *et al.*, 1975).

When ripening at a temperature of 15 °C in a narrow calibre casing the pH will not drop below about 5·2. This is reached after 14 days, by which time the water activity has dropped to below 0·93 and continues to drop with the drying of the sausage to below 0·90 after 21 days. At these a_w levels many lactobacilli will be inhibited, thus preventing further lactic acid production. With increasing time of ripening the a_w will continue to decrease, intensifying the inhibitory effect on the micro-organisms in the sausage.

The results of this study indicate that the temperature of ripening directly influences the rate of development of firmness and pH fall in the dry sausage and confirm the reports by Acton *et al.* (1978) that firmness development in fermented, dried sausages appears to be related to pH reduction, heat input and moisture removal. These results also show that it is not only the heating or cooking temperatures associated with the manufacture of summer sausage and cooked salami, as reported by Acton *et al.* (1978), but also the temperature in the ripening phase which influences the ultimate firmness of raw sausage. In this study it was discovered that there was a significant increase in the firmness of the sausage once the pH dropped below 5·4. This can be most clearly seen with the 15 °C ripening temperature (see Fig. 3) where the firmness increases from 12 N to 26 N. This change in firmness is probably related to the loss of protein solubility, as reported by Acton *et al.* (1978) and Klement *et al.* (1974) who also postulated the role played by the sarcoplasmic proteins in the presence of salt where the salt-induced insolubilisation of sarcoplasmic proteins may affect precipitation of myofibrillar proteins, thus promoting better structure development than would be achieved with myofibrillar proteins alone. This interaction could explain the differences in firmness obtained between the various ripening temperatures since these differences were influenced by the rate of pH fall which, in turn, was directly related to the ripening temperature and salt-induced insolubilisation of the sarcoplasmic protein and subsequent gel formation, as reported by ten Cate (1960).

This initial development of firmness in active fermentation is related to pH reduction; however, the amount of moisture removal will influence the additional firmness development of these non-heat-processed dry sausages. By using the procedures and control parameters shown in this study, further experimentation can be carried out to evaluate the influence of varying inputs such as casing calibre, carbohydrate type and content, relative humidity and processing schedules, which are important in the technology of raw sausage production.

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