::26 Calculation of water activity in industrial sausage production.

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Introduction.

Water activity ($a_W$) is a very important property of foods in relation to their keeping quality and has been introduced in EEC regulations for the assessment of meat products (Labots and Stekelenburg, 1980). Measurement of $a_W$ often requires the use of expensive, sophisticated equipment and/or complex methods of long duration and low accuracy. In salted products, $a_W$ is mainly determined by the concentration of salt in the water phase and can be calculated from salt and water content. Such calculations have been used successfully for dried (Poulter et al, 1982) and moist (Lupin et al, 1981) salted fish products. For dry sausage, it has been suggested that $a_W$ can be calculated following

$$a_w = 1.0014 - 0.6039[\frac{\%\ NaCl}{\%\ H_2O} + 0.0338] \quad \text{for } a_w \geq 0.895$$

(Demeyer, 1979) and similar equations were recently developed by Baldini et al (1983).
Demeyer (1979) expressed the concentration of water soluble compounds other than NaCl, contributing to $a_W$ as an equivalent theoretical concentration of NaCl present in the initial sausage batter, to be added to the concentrations of NaCl determined. From an estimated initial $a_W$ value of 0.981 the correction factor of 0.0338 was thus calculated.
Although $a_W$ values could be calculated with sufficient accuracy, calculation slightly underestimated measurement at very high $a_W$ values, whereas at very low values there is a slight overestimation. These discrepancies may be due respectively to an erroneous estimate of the initial $a_W$ value and to the lack of a correction for the increasing concentration of compounds other than NaCl during drying (Van Hoof, 1982).

In view of the introduction of $a_W$ calculation in our product development we have

a. derived a correction factor from experimental initial $a_W$ values due to compounds other than NaCl and
b. introduced a correction for drying in the formula

Materials and Methods.

-Preparation of sausage batters for determination of initial $a_W$.
A mixture of frozen beef and frozen pork (50/50 w/w) was cuttered with increasing amounts of lard to give batters (10 kg) containing 10,15,20, 25,30,35 and 40% w/w lard. From each batter 250g was then replaced by 250 g of additives to give (g/kg) 4 glucose, 15 sodium caseïnate, 0.7 sodiumascorbate, 2 pepper, 2 nutmeg and 1 sodium glutamate.
-Sausage ripening.
Analyses were carried out on 18 different sausages ready for sale to the retail trade and showing drying losses varying between 15 and 20%. Ripening conditions were similar to those described elsewhere (Demeyer et al, 1984).
-Analyses.
Official methods were used for analysis of water (ISO /1442 - 1973) and NaCl (ISO/R 1841 - 1970) (see also Vandekerckhove & Demeyer, 1975). Water-activity was determined using apparatus based on measurement of conductivity changes: Rotronic hygroscop DT using two measuring heads DMS 100 (Rotronic AG, Zürich) and Novasina (Zürich). Measurements were also made using an isopiestic method (Van Steenkiste & Van Hoof, 1978).
Sausages were sampled either in centre or surface regions (10 cm depth). Prior to determination samples were equilibrated at 25° ± 0.1°C in a closed container.

Results and Discussion.

a. Determination of correction factor.

Table 1 shows $a_W$ values determined on fresh sausage batters. It is clear that the presence of additives and different amounts of lard did not significantly affect $a_W$ values and an overall mean value of 0.990 ± 0.001 (mean value ± SD, n = 42) can be calculated.
From $a_W = 1.0014 - 0.6039$ X with

$$X = \%NaCl/\ \%H_2O \text{ a correction factor of}$$

$$\frac{1.0014 - 0.990}{0.6039} = 0.0189 \text{ can be calculated.}$$

This value is considerably lower than the initial value and the new formula can be written as

$$a_w = 1.0014 - 0.6039\ [\ \frac{\%NaCl}{\%H_2O} + 0.0189]\ (1)$$

Table 1. Measured $a_W$ values ($a_W.10^3$) on fresh sausage batters

| | Novasina | | Rotronic 1 | | Rotronic 2 | |
|---|---|---|---|---|---|---|
| | A - | A + | A - | A + | A - | A + |
| % Lard | | | | | | |
| 10 | 990 | 992 | 990 | 990 | 991 | 991 |
| 15 | 990 | 991 | 991 | 990 | 992 | 990 |
| 20 | 990 | 990 | 991 | 990 | 991 | 990 |
| 25 | 989 | 990 | 991 | 989 | 990 | 990 |
| 30 | 990 | 989 | 990 | 990 | 992 | 990 |
| 35 | 989 | 990 | 990 | 990 | 991 | 991 |
| 40 | 988 | 988 | 990 | 990 | 987 | 992 |

A - = without additives, A + = with additives

b. Introduction of a correction for drying.

A correction for drying can be incorporated in the formula (1) assuming that the theoretical NaCl equivalents ($NaCl_e$) behave like analysed NaCl ($NaCl_a$) giving :

$$\frac{\%\ NaCl_{e,b}}{\%\ NaCl_{e,s}} = \frac{\%\ NaCl_{a,b}}{\%\ NaCl_{a,s}}$$

with the index s referring to sausage and b to batter.
It can be derived that:

$$\%NaCl_{e,s} = \frac{\%NaCl_{e,b}}{\%NaCl_{a,b}} \times \%NaCl_{a,s}$$

Also

$$a_{ws} = 1.0014 - 0.6039\ \frac{\%NaCl_{a,s} + \%NaCl_{e,s}}{\%\ H_2O_s}$$

$$\text{or} \quad a_w = 1.0014 - 0.6039\ \frac{\%NaCl_{a,s}}{\%H_2O_s}\ [\ 1 + \frac{\%NaCl_{e,s}}{\%NaCl_{a,s}}\ ]$$

$$\text{or} \quad a_w = 1.0014 - 0.6039\ \frac{\%NaCl_{a,s}}{\%H_2O_s}\ [\ 1 + \frac{\%NaCl_{e,b}}{\%NaCl_{a,b}}\ ]$$

as $\frac{\%\ NaCl_{e,b}}{\%\ H_2O_b} = 0.0189$ it can be derived that

$$a_w = 1.0014 - 0.6039\ \frac{\%NaCl_{a,s}}{\%H_2O_s}\ [\ 1 + \frac{0.0189\ \%H_2O_b}{\%\ NaCl_{a,b}}\ ]\ (2)$$

An analogous formula can be developed using weight loss, assuming that weight loss equeals water loss.

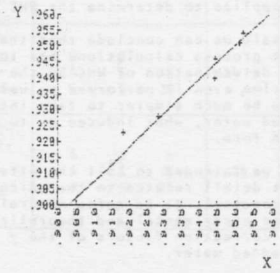
c. Evaluation of corrected formula.

The formula was used to predict changes in $a_W$ values during sausage drying using analyses of NaCl and $H_2O$ in batter and sausages. Determination of $a_W$ and analyses were carried out in the centre region (diam. 26 cm) of the sausage.
Fig. 1 shows that calculated values (X) predict measured values (n=7) following

$$Y = 1.0719\ X - 0.0680 \qquad R^2 = 0.9592$$
$$RSD = 0.0042$$

The regression coefficient and constant are not significantly different from 1 and 0 respectively.

Fig.1 Relation between calculated (X) and measured (Y) $a_W$ values during drying of sausage.



Such accuracy of prediction is comparable to prediction from $a_W$ measured by an isopiestic method (X) following

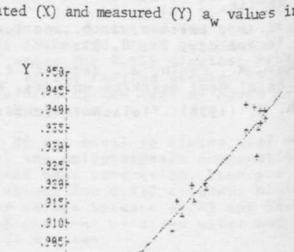
$$Y = 0.9294\ X + 0.0666 \qquad R^2 = 0.95\ \ (n = 18)$$
$$RSD = 0.0031$$

The formula was used to predict $a_W$ values measured in the surface region of sausages (Y) ready for sale to the retail trade, using NaCl and $H_2O$ analyses of the same region using estimates of % $H_2O_b$ (50) and % $NaCl_b$ (3) the regression obtained was

$$Y = 1.3198\ X - 0.3093 \qquad R^2 = 0.96\ \ (n = 18)$$
$$RSD = 0.0038$$

Accuracy of prediction was good but regression coefficient and constant were signigicantly different from 1 and 0 respectively (fig. 2).

Fig. 2. Relation between calculated (X) and measured (Y) $a_W$ values in sausages ready for sale.



This systematic over estimation may be related to erroneous estimates of % $H_2O_b$ and/or % $NaCl_b$ whereas changes in the correction factor 0.0189 may also be involved.
We are using the corrected formula (2) in product development. Similar formula's may be derived for specific product formulations, as e.g. recently applied for Frankfurter production (Lacroix and Castaigne, 1983).

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