## DRYING KINETICS OF SPANISH *SALCHICHÓN.*

Beserra, F. J.; Fito, P.; Barat, J.M.; Chiralt, A.; Martínez-Monzó, J.
Food Tecnology Department. Universidad Politécnica de Valencia (Spain). Camino. de Vera, 14. 46022-Valencia.

**Background**

The industrial manufacturing of spanish salchichon (stuffed cured meat product made with minced pork or/and beef) requires a relatively long (3-4 weeks) drying-ripening step in chambers at controlled temperature (10-45 ºC), relative humidity (65-90 %) and air velocity (0.1-2.0 m/s) (Stiebing, 1988). This step promotes the product moisture content reduction to 40-45 % while the curing reactions begun during the fermentation step continue. Throughout this period the development of the characteristic flavour, colour and texture of the product takes place (Visier, 1986). The ripening variables (temperature, relative humidity and air velocity) affect the development of quality characteristics of the salchichon at the same time as they determine the drying kinetics and therefore the process time required to reach the commercial moisture level.

**Objectives**

The aim of this work is to analyse and model the drying kinetics of salchichon as a function of the ripening variables (temperature, relative humidity and air velocity), in a reasonable range to avoid case hardening of the product, for a constant formulation obtained in a single batch.

**Materials and methods.**

*Preparation of samples and experimental design..*

*Large-White* pork meat with pH of 6.1 was used as raw material. This was cut into small pieces and frozen (-18ºC) till formulation. Partially thawed meat was minced and mixed with the other formulation ingredients (potassium nitrate and nitrite, sodium chloride, paprika, skim milk powder and freeze-dried starter cultures) previously diluted in distilled water, in a cutter machine at 4 ºC. Afterwards, the meat mass was left to ferment for 48 h at 5-7 ºC. Then, mass was stuffed in reconstituted (in 3 % lactic acid) collagen casings. The initial size of the salchichon pieces was 6 cm diameter and 19 cm length with a weight of about 500 g.

Previous to drying, a fermentation step was performed at 73 % relative humidity (φ), 25 ºC (T) and 0.3 m/s air velocity (v) in the maturation chamber. The next curing-drying step was carried out in a multi-compartment chamber where ripening variables were set according to the experimental design. Two levels of each variable were considered; relative humidity: 63 and 73 %, temperature: 15 and 21 ºC and air velocity: 0.3 and 0.7 m/s, this yielding 8 different treatments. Throughout ripening (398 h), moisture content was determined in the salchichón samples from weight control of the different pieces to obtain drying curves. The initial and final values were measured to close mass balances by drying representative samples till constant weight, according to ISO R-1442 (1979).

**Results and discussion.**

Fig. 1 shows drying curves of salchichón for the eight drying treatments. A relatively long constant rate period (120-190 h) can be inferred from these curves for all cases, this followed by a falling rate period from a critical moisture content ($X_{wc}$). These values, as well as the kinetic parameters for each period, have been determined for each treatment. Constant rate was obtained as a function of drying conditions from the slope of the respective straight line fitted to every point series $X_w$ vs. t ($r^2$>0.997). To estimate the $X_{wc}$ value, the time limit from which the correlation coefficient of the fitted straight line begins to decrease was established as the end of the constant rate period. The water content associated with this time was assumed to be the critical value from which the falling period begins. Eq. 1 was considered to estimate the individual heat and mass transfer coefficients in this period for the different conditions, taking into account the drying rate values and the thermodynamic properties of the air drying. The values of the specific area and the dry matter bulk density of the salchichón pieces were estimated from their mean diameter within the constant rate period. Table 1 shows these values and the different parameters for each treatment.

$$-\frac{\partial X_w}{\partial t} = k'\left(\frac{a}{\rho_s}\right)(x_w - x) = \frac{h_c a}{\rho r_w}(T - T_w) \qquad (1)$$

where: $X_w$: moisture content (kg water/kg dry solids); t: time (s);; a: specific surface ($m^2/m^3$); $\rho_s$: bulk density of the dry matter (kg d. m./$m^3$); $x_w$: adiabatic saturation humidity (kg water/ kg dry air); x: air absolute humidity (kg water/kg dry air); $T_w$: air wet bulb temperature (ºC); T: air temperature (ºC); $h_c$: individual heat transfer coefficient (kW/$m^2$·ºC); k': Individual mass transfer coefficient (kg water evaporated/$m^2$·s·Δx); $r_w$: boiling latent heat at $T_w$ (kJ/kg water)

Table 1 shows the critical moisture values for each treatment. These were slightly greater when air rate or temperature increased or when the relative humidity decreased, coherently with the promotion of the internal control of the process.

The falling rate period was modelled by assuming a linear decrease of drying rate with time (Eq. 2). By integrating Eq. 2 a second grade polynomial relationship between moisture content and time was deduced. So, Eq. (3) was fitted to the experimental points $X_w$ vs. t for each treatment by a multiple regression procedure with good statistical correlation ( $r^2$>0.992 ). The obtained parameters (a, b and c) are shown in table 1.

$$\frac{\partial X_w}{\partial t} = -(2at + b) \tag{2}$$

$$X_w = at^2 + bt + c \tag{3}$$

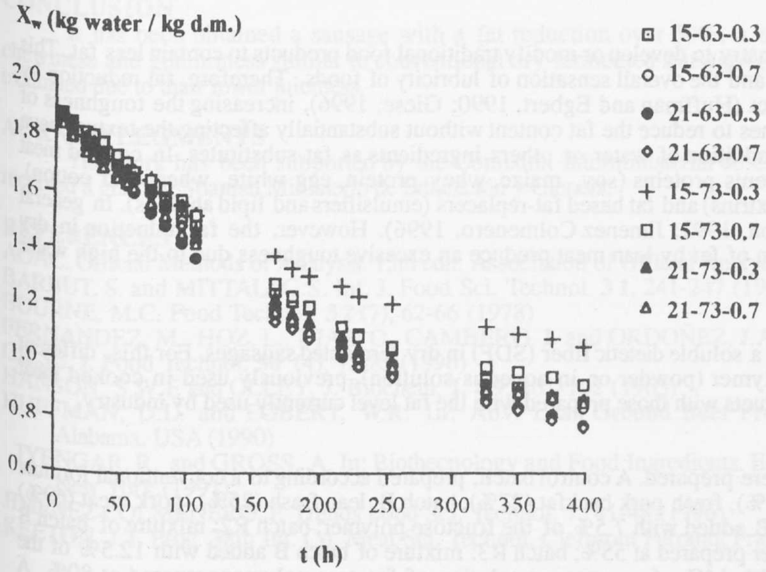


Figure 1. Drying curves obtained for the different experimental conditions (temperature-relative humidity-air velocity).

Kinetic parameters of the constant (k' and $h_c$) and the falling (a and b) rate periods were correlated with the operation variables by means of a second grade polynomial model using a step regression procedure. Eqs. 4 to 7 give the obtained relationships from which it is possible to deduce that individual heat and mass transfer coefficients increase when any of the operation variables increase, but specially when the relative humidity of the chamber rises.

$$h_c = -11.6 + 0.6T + 22.5\varphi + 3.29v - 0.63T\varphi - 0.15Tv \tag{4}$$

$$k' \cdot 10^3 = 4 - 0.45T - 1.4\varphi + 2.82v + 0.753T\varphi - 0.12Tv \tag{5}$$

$$a = -3.62 \cdot 10^{-7}T + 3.34 \cdot 10^{-8}\varphi + 7.195 \cdot 10^{-9}T\varphi \tag{6}$$

$$b = 0.015 + 1.18 \cdot 10^{-4}T - 1.92 \cdot 10^{-4}\varphi - 0.0402v + 5.88 \cdot 10^{-4}\varphi v \tag{7}$$

Table 1. Drying parameters of the different treatments in the constant and falling rate periods.

| Treatment | Constant rate period | | | | | | Falling rate period | | |
|---|---|---|---|---|---|---|---|---|---|
| | $-dX_w/dt \times 10^6$ ($kg\ s^{-1}\ kg^{-1}$ d.m.) | a ($m^{-1}$) | $\rho_s$ (kg d.s..$m^{-3}$) | k' ($kg\ m^{-2} \cdot s^{-1} \cdot \Delta x^{-1}$) | hc ($kWm^{-2} \cdot {}^oC^{-1}$) | $X_{wc}$ (kg/kg d.m.) | $a^* 10^6$ | $-b^* 10^3$ | c |
| 15-63-0.3 | 1.06±0.01 | 71.6 | 438 | 0.0039 | 0.0039 | 1.21 | 3.9±0.4 | 3.91±0.03 | 1.78±0.04 |
| 15-63-0.7 | 1.14±0.01 | 72.0 | 442 | 0.0041 | 0.0042 | 1.14 | 2.6±0.3 | 2.70±0.03 | 1.55±0.07 |
| 21-63-0.3 | 1.22±0.03 | 71.6 | 438 | 0.0037 | 0.0040 | 1.16 | 5.5±0.6 | 4.81±0.05 | 1.79±0.08 |
| 21-63-0.7 | 1.19±0.01 | 73.1 | 457 | 0.0037 | 0.0040 | 1.11 | 3.0±0.3 | 3.22±0.06 | 1.60±0.08 |
| 15-73-0.3 | 0.94±0.02 | 70.2 | 421 | 0.0047 | 0.0051 | 1.55 | 3.9±0.4 | 3.50±0.01 | 1.85±0.02 |
| 15-73-0.7 | 1.00±0.02 | 71.2 | 433 | 0.0051 | 0.0054 | 1.27 | 6.2±0.6 | 4.80±0.07 | 1.92±0.09 |
| 21-73-0.3 | 1.08±0.01 | 71.4 | 436 | 0.0051 | 0.0048 | 1.17 | 5.7±0.6 | 4.61±0.04 | 1.82±0.05 |
| 21-73-0.7 | 1.08±0.02 | 71.5 | 437 | 0.0051 | 0.0048 | 1.15 | 5.8±0.6 | 5.51±0.05 | 1.95±0.07 |

## Conclusions

The drying conditions tested allow us to avoid case hardening of salchichón giving rise to a two-steps drying behaviour: a first period, till the product reached 53-61 % moisture content, depending on the process conditions, where drying developed at constant rate, and a second period where drying rate decreased linearly with time where product reached the commercial moisture level. Curing at 63 % relative humidity and 21 ºC permitted us to reduce the drying time without any notable differences in the product quality (colour and texture) with respect to the other drying conditions (Beserra et al. 1998).

## References.


Beserra, F. J.; Fito, P.; Chiralt, A.; Barat, J.M.; Martínez-Monzó, J. (1998). Influence of ripening conditions on the ph, colour and texture development of spanish *salchichón*. Proceedings of the 44th International Congress of Meat Science and Technology. Barcelona. August 30-September 4.

Stiebing, A.; Rödel, W. (1988). Influencia de la humedad relativa sobre el desarrollo de la maduración en embutidos secos. Fleischwirtschaf Español. 2, 30,38.

Visier, A. (1986). Industria de la Carne. Salazones. Chacinería. Ed. Aedos, Barcelona.