# DEWATERING AND SALTING OF MEAT
# THROUGH IMMERSION IN CONCENTRATED SOLUTIONS AT LOW TEMPERATURE.

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## ABSTRACT

Partial dewatering of meat (beef) pieces was achieved through soaking them in mixed concentrated solutions (sucrose/salt or corn syrup/salt) at low temperature (10°C). Water loss, sugar gain and salt gain kinetics, as well as sugar/salt interactions were studied. Results show how the presence of sugar can enhance water loss, and hinder salt entrance, which proves to be particularly interesting as an alternative to traditional meat processing. In fact, process time duration can be reduced, and salt entrance better controlled.

## INTRODUCTION

Various traditional food processing operate with a difference of concentration between the food, whole or in pieces, soaked in a concentrated solution. These are mainly salting, e.g. cheese making, fish or meat curing processes , candying, and semi-candying of fruit. Salting and candying consist in furthering solute penetration into the product, and limit water loss, thanks to chemical or heat pre-treatments of the product, and use of low interface concentration difference between product and solution. For fish and meat, this impregnation stage is often followed by air-drying and/or smoking and/or fermentation complementary treatment.

Recently, there has been increasing interest in treatments of food items in higher concentration solutions ( 60 to 70 g of solute/100g solution) so as to obtain a significant water removal with a controlled solute incorporation. The penetration of solute in the food item may be expected for stabilization (water activity lowering, antifungal, antioxyding agent), nutritional interest (vitaminic or mineral compound), organoleptic interest (flavour, texture).These techniques have been refered to as "Osmotic dehydration" (Ponting et al., 1966), or more recently as "Dewatering and Impregnation Soaking Processes" (Raoult-Wack et al.,1991a), so-called "DIS processes". Most application to date concern fruit and vegetable soaked in sugar concentrated solutions, for temperature higher than 30°C. The composition of the concentrated solution is a key-factor of DIS processes. Sucrose or sodium chloride as well as blends sugar/salt are mostly used. Solute efficiency as a dewatering agent is related to high solubility in water so as to implement highly concentrated solutions, and to low migration speed in the food- and from this point of view, the use of solutes with higher molecular weight is favorable.- so as to maintain high interface concentration difference between food and solution. Generally, both requirements ( solute efficiency as a dewatering or impregnation agent) are conflicting.

Use of mixed blends, e.g. sugar/salt (50/10 or 45/15 g of each per 100 g solution) may provide respective advantages of each solute (Islam and Flink, 1982, Lenart and Flink, 1984). Moreover, interaction effects (synergetic or antagonistic) may be observed. For instance, presence of salt can hinder the formation of a sugar surface cake layer (Lenart and Flink, 1984). Salt entrance can also be limited by the presence of sugar (Bolin et al., 1983; Lenart and Flink, 1984; Le Maguer, 1988). If the molecular weight of the solutes is slightly increased (for instance, salt replaced by simple sugars or simple sugars replaced by polyosides), it is possible to decrease solute gain for an equivalent water loss, which results in a greater weight reduction (Lerici et al., 1985). Similar observations were made by Islam and Flink (1982), replacing salt by sugar.

The objective and originality of the present work is to study the interest of sugar/salt blends for DIS processing of meat with subsequent water loss at low temperature, for which very little work has been done so far .Besides, this work is partially devoted to further study of salt and sugar interactions in DIS processes thanks to experimental design, which has not been done to date.

## MATERIALS AND METHODS

Beef is cut into cubes (initial side dimension $12. 10^{-3}$ m) or parallelepipedic filets (initial side dimension $150 \times 60 \times 8 \times 10^{-9} m^3$ for kinetic study and $70 \times 70 \times 8 \times 10^{-9} m^3$ for experimental design). Let us denote by $w_w(t)$, $w_{st}(t)$, $w_{su}(t)$, and $w_{fat}(t)$, the weight fraction of water, salt, sugar and fat respectively in the product at time t.

Initial contents of the meat studied are

Water content = 72.0 %  Salt content = 0.05 %  Fat Content = 4.0

Concentrated solutions were prepared by blending sugar (sucrose or corn syrup DE 38) and sodium chloride in variable proportions, according to experimental design specification (see below). At t=0, filets or cubes were placed in containers previously filled up with syrup in excess, brought up to the desired temperature, and provided with hermetic lids. These containers were placed in an agitated and temperature controlled bath at 10°C. At time t, a container was taken. Three samples were removed from the syrup, quickly rinsed (3 seconds) and blotted dry in order to remove some of the excess of coating solution .Each sample was analysed. Water content was measured by dessication in an oven at 103°C for 24 hours. Salt content was estimated by measurement of free chloride ions with a millivoltmeter (Tacussel-BX1) in a sample of 1 g mixed in 50 ml $HNO_3$ (0,3 N). For sugar content, sample extraction was achieved after ebullition in ethanol at 80°C, concentration in a vacuum rotavapor, centrifugation and filtration (0,2 micron). Sugar content was measured by HPLC analysis with a silicon dioxide column with amino-acid splicing (NH2) and a constant-flow pump (1,2 ml/min). Fat content was obtained by the Soxhlet method. Water loss ( noted WL), salt gain (noted StG) and sugar gain (noted SuG), expressed in g/100g initial product, were inferred according to the following relations (Eqs 1 to 3):

$$WL = w_w(0) - w_w(t) \frac{M(t)}{M(0)} \quad (1) \qquad StG = -w_{st}(0) + w_{st}(t) \frac{M(t)}{M(0)} \quad (2)$$

$$SuG(t) = w_{su}(t) \, \backslash f(M(t); M(0)) \qquad (3) \qquad \text{Where } M(t) : \text{weight of sample at time t}$$

An experimental design - Doehlert network- (Doehlert, 1970) with response surface methodology was used, in order to take into account interactions. The center point of the experimental range was defined by $C_{st} = 175$ g/l water; $C_{su} = 950$ g/l water; t=4h54. Corresponding overall concentration of the solution is 53 g solute/100 g solution. Experimental kinetic studies were carried out for the concentrations corresponding to the center point, during 48 hours for filets and 24 hours for cubes. A second degree polynomial model was chosen ( Eq. 4) for the description of the response variables Y (WL, StG, and SuG) as a function of the factor variable X:
$X_1$ : salt concentration g /l water, $C_{St} = [0;350]$; $X_2$ : sugar concentration g /l water, $C_{Su} = [0;1900]$; $X_3$ : ln(t), t = [1h;24h]

$$Y = \Sigma a_i X_i + \Sigma a_{ii} X_i^2 + \Sigma a_{ij} X_i X_j \qquad (4)$$

Where $a_i$ represent the linear , $a_{ii}$ the quadratic , and $a_{ij}$ the interaction effects of the factors. Factor levels were 5 for $X_1$, 7 for $X_2$, 3 for $X_3$. The experimental design consisted of a set of 15 experimental runs, including 3 repetitions at the center point. From experimental results, model coefficients were calculated by multiple linear regression and response surfaces were drawn, using *statgraphics* software (STSC Inc., 1991) The regression and coefficient validity were controlled by statistical tests (determination coefficient $R^2$, Fisher test ).

## RESULTS

### Mass Transfer Kinetics

Figures 1 presents the variations of WL, StG and SuG versus time for beef filets soaked in salt/sucrose blends for the center point concentration conditions. Changes in slopes allow the distinction of two phases. At first (phase 1: 0 to 10 hours) solute gain and water loss are rapid. Then, fluxes decrease progressively (phase 2 : 10 to 48 hours).WL, StG and SuG obtained for beef filets up to 48 hours are 35%, 3% and 6% respectively. Figure 2 shows that for cubes, similar variations are observed as for filets but with shorter time duration (after 5 hours, WL=31%,StG=4%, SuG=8%; after 24 hours, WL=45%, StG=4%, SuG=12%).
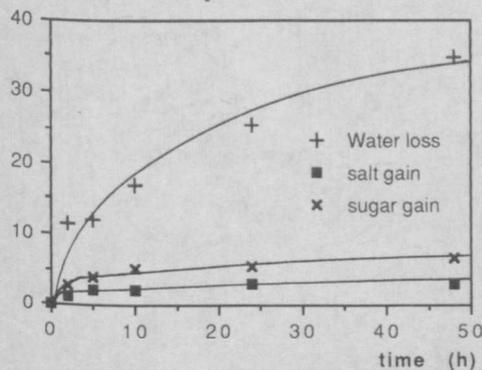
WL, StG, SuG (% initial product)



WL, StG, SuG (% initial product)



Figure 1 : Mass transfer kinetics of beef filets soaked at 10°C in salt/sucrose solution (Cst = 175g/l water, Csu = 950 g/l water).
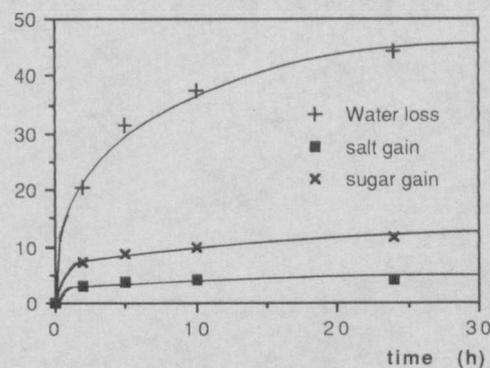
Figure 2 : Mass transfer kinetics of beef cubes soaked at 10°C in salt/sucrose solution (Cst = 175g/l water, Csu = 950 g/l water).

### Factors Effects

Effects ( coefficient value and signification level) inferred from the experimental design results for beef filet soaked in salt/sucrose solution are given in Table 1, as an illustration.

| Coefficient | WL | | StG | | SuG | |
|---|---|---|---|---|---|---|
| | | | | response | | |
| **linear** | | | | | | |
| a1 | 5.37 | * * * | 2.71 | * * * | -1.79 | * * * |
| a2 | 10.3 | * * * | -3.14 | * * * | 1.98 | * * * |
| a3 | 13.6 | * * * | 1.25 | * * * | 2.43 | * * * |
| **quadratic** | | | | | | |
| a11 | -4.27 | * * | -0.57 | | 1.02 | * * |
| a22 | -10.8 | * * * | 2.15 | * * | -3.67 | * * |
| a33 | - - - | | -0.483 | | - - - | |
| **interaction** | | | | | | |
| a12 | -9.55 | * * | -3.43 | * * * | -1.04 | * * |
| a13 | -3.1 | | 1.43 | * * | - - - | |
| a23 | 7.35 | * * | -1.05 | * | -0.75 | * |
| **constant** | | | | | | |
| a0 | 25.3 | | 2.79 | | 5.95 | |
| **R 2** | 0.973 | | 0.97 | | 0.903 | |

$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_{11}X_{12} + a_{22}X_{22} + a_{33}X_{32} + a_3X_3^2 + a_{12}X_1X_2 + a_{13}X_1X_3 + a_{23}X_2X_3$

where X1 = salt concentration; X2 = sugar concentration; X3 = ln(time)
***,**,*coefficient significant at P<0.1%; P<1%; P<5% respectively.
- - - non significant coefficient

TABLE 1: Experimental design results: Factors effects

Effect on water loss : time duration and sugar concentration have prevalent and similar linear effect. The positive value of the interaction coefficient show that they have a synergetic action. The overall effect of sugar concentration is enhanced by the quadratic term, which suggests a maximum for WL. On the contrary, the linear effect of salt concentration is lower, accompanied however by an antagonistic action with sugar concentration (salt/sugar interaction) The response surface given in Figure 3 shows the influence of salt and sugar concentration on WL at 4h54 (corresponding to center point time duration). In the range of low sugar concentrations (0 to 950 g/l of water), a favorable effect of salt concentration on WL is observed. For higher sugar concentration however, salt concentration effect is weak. Salt/sugar interaction is revealed thus high sugar concentration.
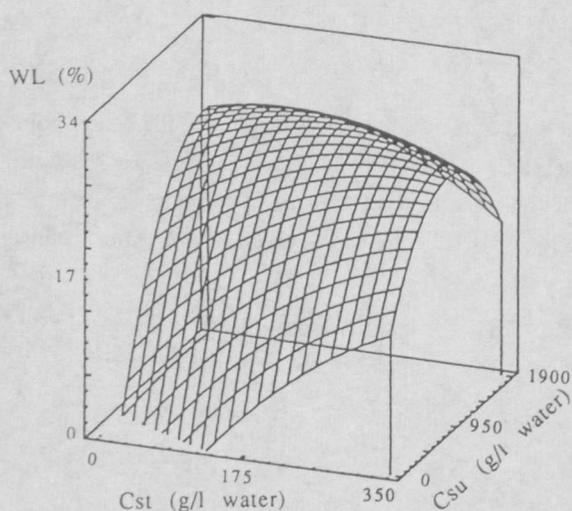


Figure 3: Response surface
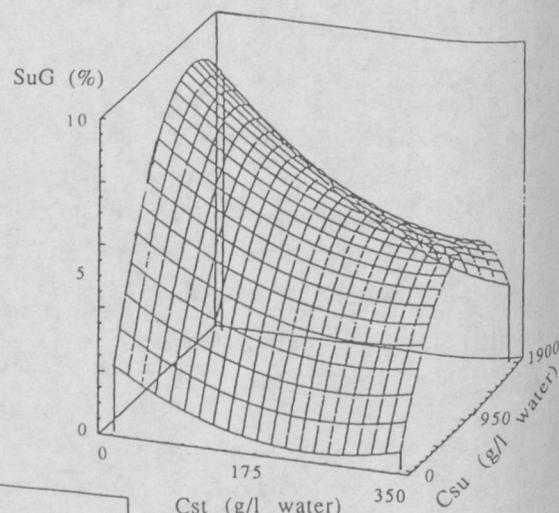PE= f(Cst, Csu) at 4h54



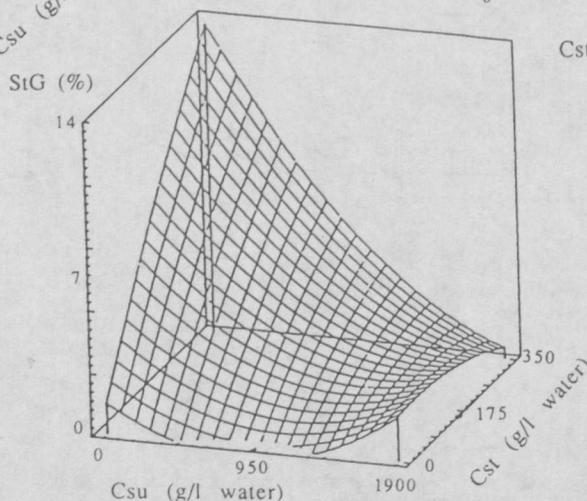Figure 5: Response surface
SuG= f(Cst, Csu) at 4h54



Figure 4: Response surface StG= f(Cst, Csu) at 4h54

<u>Effect on salt gain</u> : Sugar concentration has great negative effect , enhanced by the quadratic term , which suggests a minimum for salt gain. The antagonistic effect between salt and sugar concentration is similar to the positive effect of salt concentration. Time duration effect is linear. Figure 4 shows the influence of salt and sugar concentration on salt gain at 4h54. In the range of low sugar concentrations,salt gain increases linearly as a function of salt concentration. For high sugar concentration, salt gain is independant from salt concentration and remains low. For instance, when $C_{su}$ = 0 and $C_{st}$ saturated, StG = 13.5%; when bothe at saturation, StG = 0.7%.

<u>Effect on sugar gain:</u> Prevalent factors are time duration - great positive linear effect enhanced by a positif quadratic term- and sugar concentration, - great positive linear effect enhanced by a negative quadratic term. Besides, both factors are antagonistic. Salt concentration has a low negative linear effect and quadratic term. Figure 5 show the influence of salt and sugar concentration on SuG at 4h54. In the range of 0 to 1900 g/l of water for $C_{su}$, sugar gain varies from 0 to 8% without any salt, and from 0 to 6,7% when the solution is saturated with salt.

## DISCUSSION

This study shows that subsequent water loss (up to 45 g/100g initial product) can be obtained with animal foodstuffs, at low temperature. Considerable time reduction can be obtained through increasing the specific surface area of the particles, but solute gain is higher, as underlined by Raoult-Wack *et al.* (1992). In this case it can be particularly interesting to use high molecular weight solute for which solute entrance is low and preliminary study has shown that it is possible to decrease solute gain under 1%. Sugar/salt interactions in mixed blends are great, particularly for high salt and sugar concentration levels. These interaction effects are illustrated by the following points :
-When $C_{su}$ increases, WL increases. The increase remains unchanged whatever the salt concentration level, which means that with mixed blends, the specific favorable effect of salt concentration on WL is hidden.
-In the range of high sugar concentration, salt gain becomes almost independant from salt concentration and time duration..

Therefore, sugar may hinder salt entrance. This effect may be related to the formation of a concentrated superficial sucrose layer, which was observed on model gels (Raoult-Wack *et al.*,1991), and vegetable product (Bolin et *al.*,1983; Lenart and Flink,1984). This effect may be enhanced by the limitation of external transfer due to high viscosity of the concentrated solution (in fact, when sugar concentration is higher than about 1330-1520 g/lof water, a maximum is observed for WL and SuG, even without any salt). This effect may also be enhanced by the matrix shrinkage observed in the case of high dewatering rates. Let us note that in our case, where proteic structures and ionic compounds are involved, additional mechanisms related to sugar/protein biochemical interactions , and ionic interactions may occur.

## CONCLUSION

These preliminary study show the interest of DIS processes for the treatment of meat product. As compared to traditional processing, it shows how the traditional salting/smoking/drying sequence could be reduced thanks to one single dewatering and impregnation soaking operation. Of course, microbiological validation should be carried out. The dewatering effect is to be related to high concentration levels implemented with mixed salt/sugar solutions, as compared to salt solutions. Moreover, salt entrance can be better controlled thanks to the sugar/salt interactions. This encouraging results can be improved by the use of higher concentrations (more than 53 g solute/100 g solution studied here), increased specific surface area, higher solute molecular and temperature. Results are to be published soon.

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