D 7

Changes in Size and Shape of Oblong Type Cans under the Influence of Cooking

STANISLAW OLEWINSKI

Polish Meat Research Institute, Warsaw, Poland.

In experiments on cooking hams convex bowl-shaped deformations of the bigger side planes of the cans were observed. This phenomenon has been a rule in traditional cooking, when the cooking vats are operated under normal atmospherical pressure. Usually it has been ascribed to the action of overpressure, which has been believed to be formed inside the cans during cooking. This traditional opinion is subject to criticism in the presented paper.

EXPERIMENTAL

Materials

The experiments were performed on hams selected of a lot of carcasses just after slaughter on the basis of their pH_1 and pH_2 values. The pH_1 values were measured 45 minutes after slaughter, and only these hams were taken for further screening, whose acidity was $pH_1 = 6{,}2$ or higher. This material was again measured as to its pH value (pH_2) 24 hours after slaughter, and all hams with a pH lower than $pH_2 = 5.7$ or higher than $pH_2 = 5.9$ were retarded. The selected material was further on screened for uniform weight (9—10 kg), uniform muscle structure and fattiness. After selection the hams were cured in the usual way and sealed in oblong type cans, whose linear dimensions were: $95 \times 165 \times 287$ mm. The netto weight of the hams was 10 lbs. The experimental cooking was performed under normal atmospherical pressure.

Methods

1. pH measurements were taken by means of a needle-type glass electrode linked to a Radiometer Model 24 E pH-meter. The m. Adductor Femoris was the site of measuring the pH value.

2. Pressure inside the cans was measured by means of a MAW recording vacuum meter. To avoid any errors originating from the presence of air in the measuring tubings, all the measuring system was evacuated simultaneously with the can prior to cooking.

3. *Temperatures* inside the cans and in the cooking vat were measured by means of thermocouples with an accuracy of 0,5° C.

4. *Changes in size* were measured by immersing the cans in a vessel fitted with an overflow tube and filled with water. The amount of water displaced by the can was weighted and taken as equal to the volume of the can (after temperature correction). Prior to cooking the cans were immersed in water which had a temperature of 10° C, and after cooking in water with a temperature equal to the final temperature of water in the cooking vat. The difference in the weight of the displaced volumes of water is taken as the increase in size the can.

5. *Deformations in shape* were measured as changes in the width of the can at half their height, where the peaks of the bowl-shaped convexnesses were situated. The width was measured by means of a device in which the bottom of the can was fastened, and which was fitted with two stainless steel probes, moving perpendicularly to the larger side planes of the can.

These probes were held in guiding sleeves so tightly as to avoid any spontaneous movement, however, loosely enough to be displaced by the expanding width of the can. The difference in distance between the probes before and after cooking is equal to the double height of the bowl-shaped convexness.

RESULTS

Table 1. *Changes in size of cans due to cooking.*

No. of means	*Volume of water displaced by the can* *prior to cooking (ml)*	*after cooking (ml)*	*Difference (ml)*
1	4241	4297	56
2	4207	4256	49
3	4237	4297	60
4	4267	4317	50
5	4257	4287	30
6	4262	4315	53
7	4227	4297	70
8	4262	4317	55
9	4207	4237	30
10	4262	4312	50
mean	4243	4293	50

Table 2. *Changes in width and height of cans due to cooking*

No. of	Width of cans(cm) before cook.	after cook.	Diff.	Height of cans(cm) before cook.	after cook.	Diff.
1	9,00	9,90	0,90	28,69	28,77	0,08
2	8,96	9,83	0,87	28,70	28,80	0,10
3	9,28	10,00	0,72	28,68	28,77	0,09
4	9,05	9,80	0,75	28,72	28,20	0,10
5	8,97	9,82	0,85	28,73	28,84	0,11
6	9,10	9,89	0,79	28,68	28,83	0,15
7	9,21	10,15	0,94	28,72	28,80	0,08
mean	9,08	9,91	0,83	28,70	28,80	0,10

Table 3. *Absolute pressure inside the cans (atmospheres)*

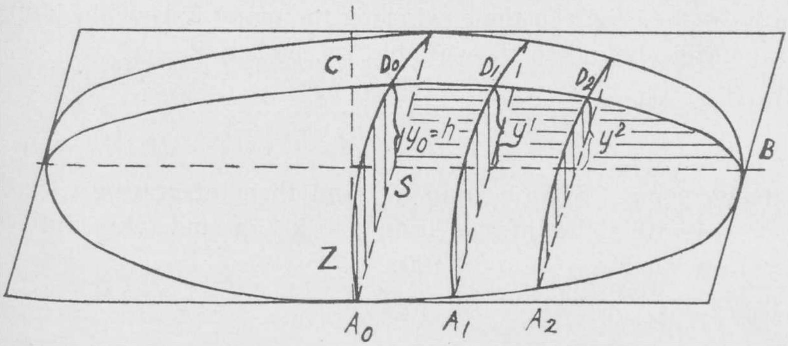
Moment of measurement	No. of measurement 1	2	3	4	5	6	mean
prior to cooking	0,10	0,12	0,17	0,10	0,15	0,11	0,13
after cooking	0,95	1,00	0,95	0,95	0,97	1,00	0,97

DISCUSSION

From tables No .1 and No. 2 it can be derived that the increase in size for the cans was at the average 50 ml. and the width of the cans after cooking was bigger by 8,3 mm than before cooking, whereas the increase in height was negligible (0,10 mm). The height of the bowl-shaped convexnesses is at the average h = 4,15 mm.

From basic knowledge in physics it should be expected that the biggest increase due to thermal expansion of the tinplate will be noticed in the height of the cans. However, the experimental results clearly indicate that this is not the case. Therefore it is interesting to know what is the proportion of the bowl-shaped deformations of the side planes »bowls» in the overall increase of the can colume.

Since the author did not find any ready-to-use mathematical formula for the volume of bowls, whose cross sections are parabolical and the base is elliptical, so this was derived as follows: The bowl (viz. fig. No. 1) was divided into four quarters and all the reasoning was made for the quarter A_oSBD_o. The following assumptions were laid as the basis for calculations:



1) the curves A_0D_0, A_1D_1, A_2D_2 and generally A_nD_n are parabolas obeying the equation:

$$z = u^n \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where: z — height of the bowl for a given »u» value.

u — distance along the minor axis of the ellipse forming the base of the bowl. The distance is read starting from the section point of the projection of the parabola on the base, with the ellipse laying on the same base.

n — exponent

2) the parabola given by equn. (1) has the following properties:

a) for $u = O$ we have $z = O$

b) for $u = u_y$ we have $z = y$

where: u_y-value for coordinate »u» at the section point of the projection of the parabola on the base, with the major axis of the ellipse laying on the same base.

The volume of the »quarter» A_0BS_0 D is given by the integral:

$$V_{A_0BSD_0} = \int_0^a \int_0^{u_y} u^n \cdot du \cdot dx \quad \ldots\ldots\ldots \quad (2)$$

where: x — distance along the major axis of the allipse, read starting from the point B

a — length of the semi-minor axis of the ellipse

Integrating equn. (1) with regard to »u» within the interval from O to u_y, and inserting $z = y$ at $u = u_y$, we get:

$$P = \int_0^{u_y} u^n \cdot du = \frac{1}{n+1} \cdot y^{\left(\frac{n+1}{n}\right)} \quad \ldots\ldots\ldots (3)$$

Again »y» is the height of the bowl along the major axis of the ellipse, and it parabolically bound to the variable »x», namely:

$$y = x^m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where: m — exponent

Introducing equn. (4) into equn. (3) and then integrating it with reference to »x» within the interval from O to x = a, and taking into account that y. = h when x = a, we obtain:

$$V_{A_0BSD} = \frac{1}{n+1}\int_o^a y^{\frac{n+1}{n}} \cdot dx = \frac{1}{n+1}\int_o^a x^{\frac{n+1}{n}} \cdot dx = \frac{n}{(n+1)(m+1)+n} \cdot h^{\frac{m(n+1)+n}{mn}}$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Hence the final formula for the volume of the »bowl» is:

$$V = \frac{4\ n}{(n+1)\cdot(m+1)+n} \cdot h^{\frac{m(n+1)+1}{m\ n}} \quad \ldots\ldots\ldots (6)$$

The numeric values for the exponents »m» and »n» can we calculated from equns. (1) and (4), namely:

$$n = \frac{\log (h)}{\log (b)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$m = \frac{\log (h)}{\log (a)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Putting the respective numeric values, i.e. a = 143,5 mm, b = 82,5 mm, and finally h = 4,15 mm into equns. (7), (8) and (6) we finally get the volume of the bowl as V = 31,37 ml, and hence the volume of the overall deformations bowls on both larger side planes of the can as: 2V = 62,74 ml.

The final value corresponds roughly with the experimentally determined change in the size of the cans.

Since the calculated volume of the deformations is somewhat bigger than the experimentally found one, and simultaneously there has been found no significant increase in the height of the cans, one comes to the conclusion that all the increase in volume is caused by the the bowl-shaped conve deformations of the larger side planes of the can.

From table No. 3 it is easily derived that no overpressure is developed inside the cans due to the cooking process under normal atmospheric pressure. Therefore the traditional opinion, ascribing the formation of convex deformations of the side walls in oblong type cans to the action of an internal overpressure, developed during cooking, has to be rejected as not substantiated.

If there were any action due to pressure differences, so the deformations should be concave and not convex, because the maximal internal pressure at the end of the cooking process is lower than the external atmospheric one (0.9 absolute atmospheres). Hence the found deformations are to be ascribed to other reasons than to the action of internal overpressure. Among these reasons the most probable seem to be:

a) thermal expansion of the contents of the cans,

b) thermal contraction of muscles along their longitudinal axes.

CONCLUSIONS

As a result of the performed experiments the author draws the following conclusions:

a) The traditional opinion ascribing the development of conve deformations of the side walls of oblong cans to the action of an internal overpressure has to be rejected as contradictory to experimental findings.

b) In contrary to expectations the increase in the height of cans due to cooking is negligible

c) An increase in the overall volume of the cans, approximately by 1 %, is evoked by the cooking process, and can be ascribed fully to the volume of the bowl-shaped conve deformations of the larger walls in the can.

REFERENCES

1. Ball C.O., Olson F.C.W.: Sterilization in Food Technology. Hill, New York 1957.
2. Flaumenbaum B.L.: Tieoreticheskie osnovy sterilizacii konservov», Kiev, 1960.
3. Gisske W. Die Fleischwirtschaft 7,550, 1961.
4. Gless A. Die Fleischwirtschaft 4,279, 1963.
5. Goldblith S. A., Joslyn M. A., Nickerson I.T.R. An Introduction to the Thermal Processing of Food. An Anthology of Food Science. Berkeley 1959.
6. Pezacki W. Technologiczne odchylenia jakości wyrobów mięsnych. Warszawa 1968.
7. Pijanowski E., Mroźewski S., Horubala A., Technologia produktów owocowych i warzywnych. PWR i L. Warszawa 1964.
8. Tyszkiewicz St., Tyszkiewicz I. Próby ustalenia optymalnych warunk'w cieplnych ze względu na wyciek i stopień denaturacji. Roczniki I.P.Ms. t. III Warszawa 1966.