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GRAPH -ANALYTICAL METHOD OF CALCULATION FOR THE DETERMINATION OF THE PROPORTION OF THE SOLID AND LIQUID PHASE IN FONDANT

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Abstract
This paper presents graphic-analytical method for determining the ratio between the solid phase (Fs) and the liquid phase (Fl) in fondant.
In the graph are plotted on the abscissa different values $\frac{Gz}{G}100$ *of the sugar concentration in the sugar solution, glucose syrup and water, and the ordinate the temperature of the syrup (t°). By completing it in the superior part with the series of experimental boiling curves of sugar solutions, glucose syrup and water, it can serve not only toillustrating the formation process of the fondant in the installation of manufactured fondant, and also at its calculation.*
The curves are also plotted Z which is the ratio of the amount of glucose syrup and the amount of water. The ratio of F_s *and* F_l *in the fondant depends on the factors mentioned above: temperature, ratioZ and ratio* $\frac{Gz}{G}100$.
On the graph the solubility of sugar from the syrop with the temperature of boiling illustrated by segment 1-4; the crystallization of the sugar in fondant recipient by segment 6-7; and the amount of liquid phase is proportional to the segment 6-8.
They conducted three practical tests of fondant and using graphic-analytical method we determined the ratio of liquid and solid phase. Depending on the value of these reports, we set the destination of the fondant of the three samples (fondant for fondant bonbons –in coverand nucleus, and for candy salon).

Keywords: graphic-analytical method, solid phase and liquid phase fondant, concentration curves

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1. INTRODUCTION

As "laboratory products" can be grouped a broad product range. They are characterized by a high food value, due to additions of materials like candied fruit, fatty kernels, Cocoa powder, egg glair.
In our country, are manufactured various kinds of laboratory products having the base preform the fondant, (Banu, 2009).
Preparation of the fondant. The fondantis characterized as a paste with a white color, with sweet taste and creamy.
In terms of the physico-chemical characteristics, is presented as a heterogeneous composed system from a solid phase (sucrose crystals of different sizes), a liquid phase comprising a saturated solution of sucrose in the presence of glucoseor invert sugar and a gaseous phase composed of air incorporated during the preparation of it, (Chung, 2000; Racolta, 2008).
The whiteness of the fondant is given by the reflection of light in the small crystals of sugar. In terms of quality, the fondant can be appreciatedaccording to the microcrystalline structure of the solid phase, and consistency is determinedby the ratio between the solid and the liquid, (Bratu, 2005).
For the fondant to be considered of superior qualityit must contain sugar crystals the size of which does not exceed 12 μ, and the ratio between the solid and liquid phase is important to provide the necessary plasticity to the destination that is to be given.
The presence of crystals in the fondant of 20 μ and even bigger, makes the fondant lose the character of cream, becoming a coarse paste. As a result of this, crystal with size over 40 μ feel when tasted, being called massaged fondant.
Fondant used in the manufacture of products by moulding in printed forms in starch (fondant candy cores, candy salon) must

present a greater plasticity, this can be done by the liquid phase growth, (Talbot, 2009).

2. MATERIALS AND METHODS

The formation process of the fondant

The method used is graphic-analytical method. Fondants are obtained by technological scheme presented in the work ,,Sugar confectionery manufacturing technology" (Bratu M, 2005).

The total balance of materials of syrup prepared from sugar, glucose syrup and water at a given temperaturecan be the following:

Gz + Gg + Ga = G

In which: Gz = sugar quantities

G_g= glucose syrup

G_a= water

G = resulted syrup

The graph in Figure 1 Sugar concentration curves are plotted $\frac{Gz}{G}100$ in different sugar solutions, glucose syrup, water, depending on the temperature.

In which: $\frac{Gz}{G}100$ is the concentration of sugar in water solution, glucose syrup and sugar.

In this graph on the abscissa different values are entered of the report $\frac{Gz}{G}100$, and on the ordinate and temperature of the syrup. The equal balance sheet above is illustrated graphically by a point.

Is the ratio of the amount of glucose syrup and the amount of water contained in the solution.

It is obvious that the quantitative ratio between the solid and liquid phase depends on the factors listed above, namely: of temperature t, of ratio Z, and of ratio $\frac{Gz}{G}100$.

In the graph is observed the fact that, the curv**e** at which Z=0 indicates the sugar concentration in a water sugar solution.

This graph was constructed experimentally by Prof.Sokolovski after making a series of research and after he made numerous experiments.

By completing it in the superior part with the series of experimental boiling curves of sugar solutions, glucose syrup and water, it can serve not only to illustrating the formation process of the fondant in the installation of manufactured fondant, and also at its calculation.

Thus, assuming that the fondant is characterized by the following parameters:

$\frac{Gz}{G1} \times 100 = 80\%$ – the sugar concentration in the fondant syrup

Z_1=0,30 - ratio of glucose syrup and water

$T_1=12^0C$

Glucose syrup has humidity of 18,5%.

In the graphic, point 1corresponds to indicated sugar content in the solutionat the temperature of 12^0C. At this temperature, the sugar concentration in saturated solution with coefficient Z1 is determined by point 2. The concentration of sugar in this solution at a temperature of 12^0C is equal to about 57,2 %. This means that not all sugar was dissolved.

We note with $G^0$the quantity of sugar, in kg, that rests undisolved from 100 kg of mixture.

In 100 kg of mixture we find $100 - \frac{Gz}{G1} \times 100$ solvent mixture.

Solvent: $D = 100 - \frac{Gz}{G1} \times 100$

1 kg solvent dissolves:

$$\frac{Gz}{G1} = \frac{57,2}{100 - 57,2}\text{kg sugar}$$

According to the following calculation:

$$100 - \frac{Gz}{G1} \times 100\text{solvent ... dissolve}\frac{Gz}{G1}\text{x}100\text{sugar}$$

1 kg of solvent ....will dissolve X sugar

$$\text{X sugar} = \frac{\frac{Gz}{G1} \times 100}{100 - \frac{Gz}{G1} \times 100} = \frac{\frac{Gz}{G1} \times 100}{100 \times G1 - 100 \times Gz \,/G1}$$

$$\text{X sugar} = \frac{Gz}{G1} \times 100 \times \frac{G1}{100(G1 - Gz)} =$$

$$= \frac{Gz}{G1-Gz} = \frac{57,2}{100-57,2} \text{ sugar dissolved}$$

The entire amount of solvent is able to dissolve

$$(100 - \frac{Gz}{G1} \times 100) \times \frac{57,2}{100-57,2}$$

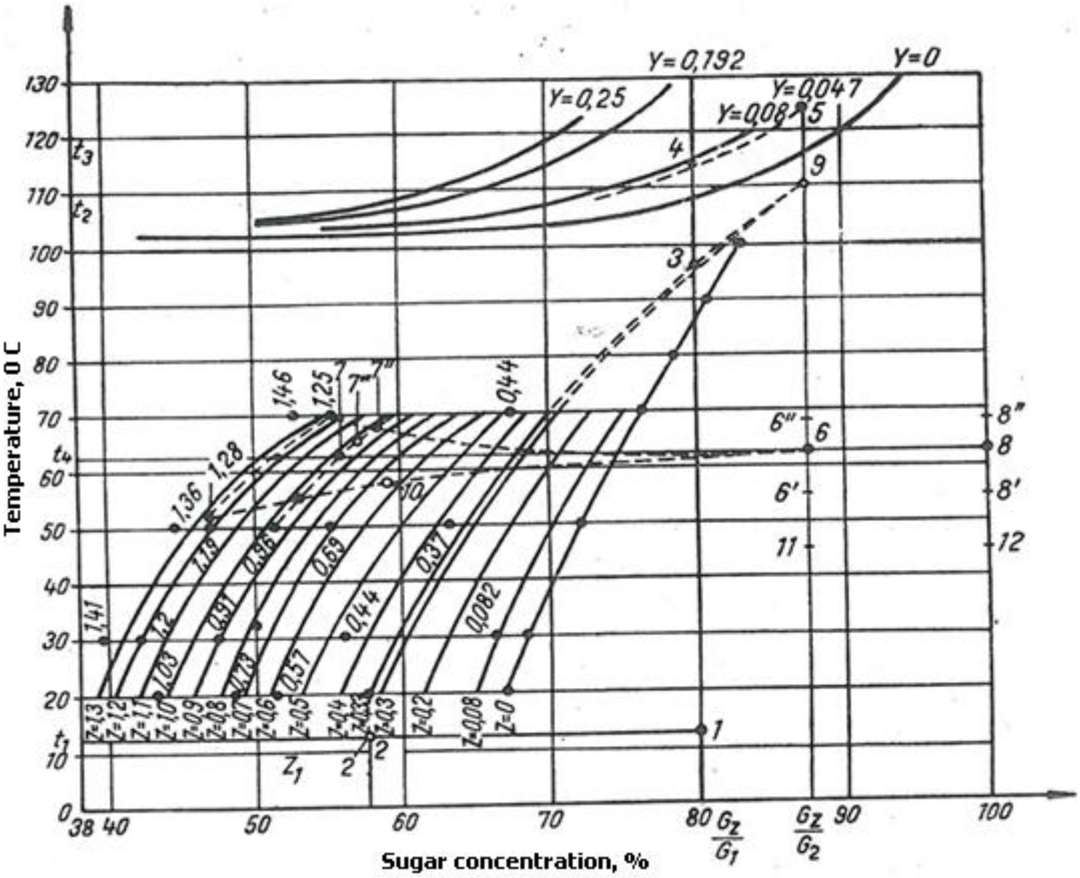

Fig 1.The graph of formation of the fondant in the installation of fondant

In 100 kg mixtureone can find:

$100 - \frac{Gz}{G1} \times 100$ solvent (glucose syrup + water) and undissolved sugar G^0_z = sugar – sugar dissolved

$$G_z^0 = \frac{Gz}{G1}\times 100 - \left(100 - \frac{Gz}{G1}\times 100\right) x$$

$$\times \frac{57,2}{100-57,2}$$

$$G_z^0 = \frac{Gz}{G1}\times 100 - \frac{57,2 \times 100}{100-57,2} +$$

$$+\frac{Gz}{G1}\times\frac{57,2}{100-57,2} x100 \;;$$

$$\frac{G_z^0}{100}\times(100-57,2) =$$

$$= \frac{Gz}{G1}(100-57,2) - 57,2 + \frac{Gz}{G1}\times 57,2$$

$$\frac{G_z^0}{100} = (100-57,2) = \frac{Gz}{G1}\times 100 - 57,2$$

$$G_z^0 = \frac{\frac{Gz\times 100}{G1} - 57,2}{100-57,2}\times 100$$

From this relation we calculate the amount of sugar undissolved which is proportional to the segmental 1-2.

$$G_z^0 = \frac{80-57,2}{100-57,2}\times 100 = \frac{22,8}{42,8}\times 100$$

$$G_z^0 = \frac{22,8}{42,8}\times 100$$

$G_z^0 = 53,3$ kg undissolved sugar

For the entire amount G_1, the undissolved sugar equals:

$$Gz\frac{53,3}{100} = 0,533\ G1$$

By heating the solution of sugar it increases its temperature, the sugar content in the dissolver being equal. On the graphic the process follows **curve 1-3**.

At the temperature of **point 3** the entire amount of sugar mixture was dissolved, and in the dissolver is a saturated sugar solution in water and glucose syrup. This solution is heated in continuationuntil boiling. This process occurs on **line 3-4**.

Resuming from the beginning,line 1-4 correspondsto the whole process of heating of the solution of sugarup to the boiling point. Line 1-4 is shown parallel to the ordinate, although in reality it has some deviation, because in the process of heating is evaporated to about 0,3% from the humidity, which leads to a change in the concentration.

For simplicity, however,, is considered line 1-4 parallel with the ordonate.

Point 4 is at the intersection of the right $\frac{Gz}{G1} = \text{const.}$ with one of the curves of temperature of boiling of the solution sugar-water-syrupof glucose which are listed at the top of the graph.

In order to determine the curve up to where should be extended the right $\frac{Gz}{G1} = \text{const.}$ is determined the report of dry substance of the glucose syrup compared to the sugar.

$$Y = \frac{Gg(1 - Ug)}{Gz}$$

In which: U_g = humidity of glucose syrup

Equality: $G_2 = G_z + G_g + G_{2a}$

In which:

G_2 = the amount of concentrated syrup

G_z= the amount of sugar in the syrup concentrate

G_g= the amount of concentrated syrup of glucose syrup

G_{2a}= the amount of water in the concentrated syrup

$G_g = G_1 - G_z - G_{2a}$; $Gg = G_1 - G_z - \frac{Gg}{Z}$; $G_{2a} = \frac{Gg}{Z}$

$Gg = Z \times Ga$; $Z = \frac{Gg}{Ga}$

$Z \times Gg = ZG_1 - ZG_2 - Gg$

$Z \times Gg + Gg = Z(G_1 - G_2) = Gg(z + 1)$

$G_g(1+Z) = Z(G_1 - G_2)$

$$Gg = \frac{Z}{1 + Z}(G1 - G2)$$

$$Y = \frac{Gg(1-Ug)}{Gz} \quad \text{(we replace Y)}$$

$$Gg = \frac{Z}{1 + Z}(G1 - Gz)$$

$$\Rightarrow Y = \frac{(G1 - Gz) \times \frac{Z}{1 + Z}(1 - \frac{Ug}{100})}{Gz}$$

$$Y = \frac{1 - \frac{Gz}{G1} \times \frac{Z}{1 + Z} \times (1 - \frac{Ug}{100})}{\frac{Gz}{G1}}$$

$$Y = \frac{(1 - 0{,}80) \times \frac{0{,}30}{1 + 0{,}30} \times (1 - 0{,}185)}{0{,}80}$$

$Y = 0{,}047$ (determined from curve 5, $\frac{Gz}{G2}$)

Point 4 belongs to the curve of the temperature of boiling of the syrup withthe coefficient found Y. In continuation the syrup is boiling in the coin of the concentrating deviceand its moisture is evaporated, so syrup concentration increases at the same time with increasing its temperature, Y remaining constant.

The concentration of the syrup is illustrated on the graph by **curve 4-5** at which Y is constant.

Point 5 corresponds to the final concentration of the sugar in the syrup $\frac{Gz}{G2}$. Usually, this size is not known and that is why the controlis by humidity syrup. The humidity of the syrup is not illustrated in the graph. One can find just humidity of the simple syrup water-sugar (without glucose syrup). For this syrup humidity is determined by the segment between the point on the curve of the temperature ofboiling of the syrup Y = 0 and the line of100% (the sugar concentration).

To be followedwe will showwhich is the link between concentration of the sugar in the fondant syrup and the humidity of the syrup.

For this it is written the balance of materials in the concentrated syrup:

$G_2 = G_z + G_g + G_{2a}$

In which:
G_2 = the amount of concentrated syrup
G_z= the amount of sugar in the syrup concentrate
G_g= the amount of glucose syrup in the concentrated syrup
G_{2a}= the amount of water in the concentrated syrup
In this equality is replaced the amount of glucose syrup by the amount of sugar and the ratio Y.

$$G_Z + \frac{YGz}{1-Ug} + G_{2a} = G_2$$

The amount of water in the syrup, neglecting the humidity from the sugar is determined with the relation:

$$\frac{Y}{1-Ug} \times UgG_Z + G_{2a} = UG_2$$

In which: U= humidity of the concentrated syrup
Y = the ratio: dry substance of glucose syrup / the amount of sugar
Solving the last two equalities we obtain:

$$\frac{GZ}{G2} = \frac{1-U}{1-Y}$$

Last expression allows to determine also the sugar concentration in the syrup, if it is known the humidity of the syrup U and the amount of dry matter from the glucose syrup
and the humidity of the syrup by knowing the concentration of sugar.
For example, the concentrated syrup with $\frac{Gz}{G2} = 87\%$ and y=0,047, will have humidity

$$U = 1 - \frac{Gz}{G2}(1+Y) = 1 - 0{,}87(1+0{,}047)$$

$= 0{,}0891$; U=8,91%

By passing phase fondant, the concentrated syrup turns into fondant recipient in a product in two phases: solid phase (fine sugar crystals) and liquid phase (sugar solution with glucose syrup and water). At temperature t_4 sugar crystallization starts in the fondant recipient. The body of the recipient is equippedwith cooling cover for the crystallization to be realized at t_4 constantly, process graphically illustrated by **the right 6-7**. Point 7 is located at the intersection line t_4=constant with the curve of the concentration of the solution of sugar with Z_2, ie from another quality of the solvent (due to the evaporation of the moisture).

$$Z2 = \frac{\frac{GZ}{G2}x\frac{Y}{1-Ug}}{1-\frac{GZ}{G2}(1+\frac{Y0}{1-Ug}}$$

In this example $\frac{GZ}{G2} = 87\%$, Y =0,047,

Ug=0,187, then Z_2=0,63

As a result of the crystallization the solid phase is obtained represented by the sugar crystals which are proportional with segmental 6-7, meaning:

$$Gz = G2\frac{\text{segment } 6-7}{\text{segment } 8-7}$$

The amount of crystals will be:

$$\frac{GZ}{G2}x100 = \frac{\text{segment } 6-7}{\text{segment } 8-7} =$$

$$= \frac{87-55{,}5}{100-55{,}5}x100 = 70\%$$

and the amount of liquid phaseis proportional to segmental 6-8, meaning

$$Gz = G2\frac{\text{segment } 8-6}{\text{segment } 8-7} = \frac{100-87}{100-55{,}5} = 30\%$$

(Nicolescu and Petrescu, 1967)

3. RESULTS AND DISCUSSIONS

Since the liquid phase and the solid phase of fondant mass is in direct contact, they react with each other after preparation of the fondant. This means that from the mother solution the crystal sucrose is separated which helps improve the solid phase.
With the loss of sucrose, the liquid phase, becomes less viscous so that, the fondant

acquires plastic properties much more advanced, (Bratu, 2005).
This balance appearing between the two phases of the fondant, can change in a negative sense. The reasons can be external or internal causes.
By the time, for some outside reason, the fondant loses humidity, the liquid phase takes place, and a sugar quantity crystalizes thus enriching the solid phase, resulting the strengthening of the fondant.
If the fondant contains a large amount of reducing substance, it can absorb water from the atmospherethus leading to an increase of the liquid phase which will contain a quantity of crystals of sugar of small dimensionsthat will dissolve, thus resulting the transformationof the fondantin a moisture and soft paste, difficult to work (used for making sorbet, (Shakuntala et al, 2005).
It is therefore very important to pay attention in the preparation of the fondant, taking into account that a very important role plays its destination. Therefore, depending on this, must be secured and strictly respect the technological parameters which are necessary to producing the according fondant mass (Banu, 2013).
In Table 1 the destinations of the fondant are presented depending on the ratio liquid phase / solid phase.

Table 1. Destination of the fondant depending onthe ratio liquid phase / solid phase

Destination of the fondant	Ratio Fl/ Fs
Salon Candy	0,55 ÷ 0,57
Paves	0,4 ÷ 0,45
Core of fondant candies	0,30÷ 0,35
Covering fondant candies	0,45÷ 0,5

Sample 1 :

It is chosen: -in the graph the ratio of $\frac{Gz}{G1}$which is the concentration of sugar in the fondant syrup and it is equal with 80%.
-Z_1 = 0,30, and is the ratiobetween the quantity of glucose syrupand water

$$\frac{Gz}{G1} \times 100 = 80\%$$

Z_1 = 0,30; $Z1 = \frac{Sg}{1} = 0,3$

Zh = 80 kg; Ts = 100 kg
In which:
Gz= the amount of sugar in the concentrated syrup
Z1= the ratio of the amount of glucose syrup and the amount of water contained in the solution
A=water quantity
Zh=sugar quantity
Ts= total syrup quantity
Zh + Sg+ A = 100 (total syrup)
80 + 0,3 A + A =100
1,3 A = 100 – 80 = 20 →A = 15,38 kg, Sg=4,62 kg
In the mixture we find: Zh= 80 kg, A = 15,38 kg, Sg = 4,62 kg
From the graph, corresponding $\frac{Gz}{G1}$ correspondsthe point 2, so that it results the amount of dissolved sugar in the sugar solution, glucose syrupand waterwhich is of 57,2Kg
According to the graph, the solid phasewill be given by segment 8-7.

$$Fs = \frac{80 - 57{,}2}{100 - 57{,}2} = 53{,}27\text{Kg}$$

Fl=20 kg; Ratio Fl/Fs =0,37

Depending on this ratio, the destination of the fondantis suited for fondant candy cores.

Sample 2

It is chosen:

$$\frac{Zh}{A} = \frac{4}{1}$$

4 Zh + 0,3 Zh +Zh = 400
Zh = 75,47 →From the graph, it results the quantity of dissolved sugarwhich is of 57,2 kg
Water = 18,86 kg, Sg = 5,66 kg.

$$Fs = \frac{75{,}47 - 57{,}2}{100 - 57{,}2} = 42{,}68 \text{ kg}$$

F_l =24,52 kg

Ratio Fl/Fs =0,57
Depending on this ratiothe destination of the fondant is for producing the salon candies.

Sample 3

It is chosen: $\frac{Zh}{A} = 4{,}5$

Zh=78,15kg; A=16,8; S_g=5,04

$$Fs = \frac{78{,}15 - 57{,}2}{100 - 57{,}2} = 48{,}95 \text{ kg}$$

F_l=21,84 kg

The report Fl/Fs=0,45

Depending on this report, the destination of the fondant is for producing the cover of the condant candies.

5. CONCLUSIONS

By increasing the percentage of glucose syrup, increases the amount of liquid phase and the fondant becomes more plastic, thus indicated for use at products obtained by pouring such as salon candies, different creams of fondant, core fondant (Ifrim, 2009).

The fondant used for coating fondant candies as well as the one for pavesmust be more consistent, so it must contain a bigger quantity of solid phase.

The excess of liquid phase can be separated at the surface in the form of a syrup, which, when it is less concentrated, constitutes an environment friendly to the development of mould. When mixing sorbet.

By varying the ratio of the quantity of sugar and water (according to the three samples) we realized three samples of fondant, to which according to the report liquid phase: solid phase we gave the proper destination according to the table presented.

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