

## Prediction of the Hardness of Chocolate and Compound Coatings

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### Introduction

The audible snap of a chocolate bar and the hardness of the chocolate as it's first bitten into are both important parameters and indicators of quality to the consumer. The snap and hardness and, to a large extent, the contraction of chocolate are all properties that are closely linked. They are also properties that are closely related to the fat phase of the chocolate.

This would then imply that a knowledge of certain properties of the fat phase should help us to define and predict the hardness of the chocolate.

Hardness of chocolate and of coatings can be measured in a number of ways using texture analysers. Most commonly, it is measured using either a three-point break test (often related to the snap of the chocolate) or a penetration measurement (often related to hardness 'at first bite').

Having said that there is a relationship between the hardness of chocolate and some property of the fat phase, what exactly relates to what?

### Hardness, Penetration and Solid Fat Content

Firstly, hardness can be defined and calculated from penetrometry measurements. Soeters described this relationship as:

$$H \text{ (kg/cm)} = 15.069 * \frac{100}{p}$$

where p is the penetration in mm/10 (using a 9.18 degree cone with a blunted tip, 0.15cm diameter and a total weight of 100g.)

The hardness of a chocolate or compound coating is an expression of its structure and solidity. Since it is the fat phase of such products that defines the structure it might be expected that the chocolate hardness will be related to the structure and solidity of the fat phase.

The solidity of fats can be easily measured by using NMR to determine the solid fat content at specific temperatures. The question, then, is does the hardness of chocolate and compound coatings at, say, 20°C correlate in any way to the solid fat content of the fat phase at the same temperature? If it does, then simply measuring the solid fat content will give a good indication of the hardness of the chocolate without the need to go through much more complex actions of making, moulding and storing chocolate.

## Experimental Basis

To test this theory we made two sets of chocolate and compound products. One set was based on cocoa butter with and without milk fat, and with and without vegetable fat. The second set of products were based on cocoa butter replacers, both lauric and non-lauric based.

Because cocoa butter-based chocolate crystallises in a completely different type of structure than compound coatings it is necessary to treat these as two completely distinct groups of product. Combining them into one group gives, as will be seen, a much poorer statistical correlation.

### Cocoa Butter Based Chocolates

Five different chocolate compositions were examined, each designed to have a different solid fat content at 20°C and each designed to exhibit a different hardness.

The fat phases of the chocolate samples were:

- 100% cocoa butter
- 90/10 cocoa butter/milk fat (i.e. a low milk-fat milk chocolate)
- 80/20 cocoa butter/CBI (i.e. a vegetable fat permitted within the new EU regulations but which is harder than cocoa butter and therefore acts as a Cocoa Butter Improver)
- 80/20 cocoa butter/CBE
- 80/20 cocoa butter/liquid vegetable oil (this is an added vegetable fat which would not be permitted under the new EU regulations but which was included to give a soft extreme).

It should also be noted that, depending on the total chocolate composition, a vegetable fat usage as high as 20% of the fat phase, may also be excluded by the EU chocolate regulations. Such high levels were, however, used in this study to exaggerate the differences between the chocolates.

The solid fat content at 20°C and the hardness at 20°C are shown in Table 1. Linear regression was used to obtain a statistical correlation between the solid fat content and the hardness. The experimental results and the predicted hardnesses from the linear regression are shown in Figure 1.

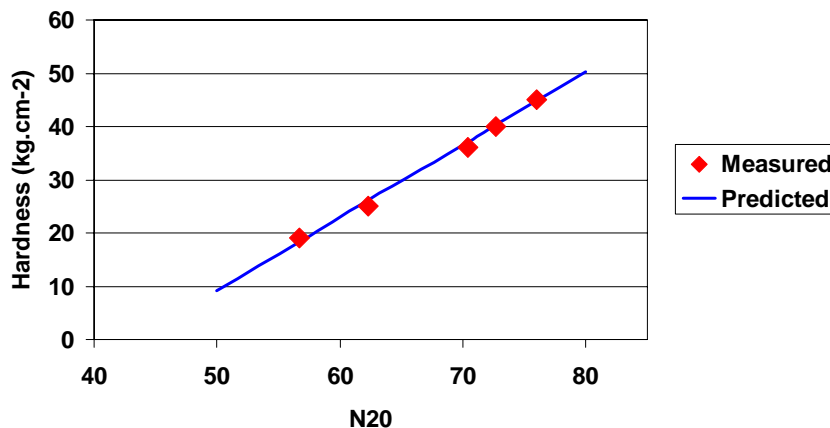
Table 1      Solid fat content and Hardness of chocolates at 20°C

Fat phase	N20	Actual hardness kg.cm <sup>-2</sup>	Predicted hardness kg.cm <sup>-2</sup>
100% CB	72.1	40	40.3
90/10 CB/BU	62.3	25	26.1
80/20 CB/CBI	76.0	45	44.8
80/20 CB/CBE	70.4	36	37.1
80/20 CB/Oil	56.7	19	18.4

The statistical correlation by linear regression gives a 'best fit' relationship of:

$$\text{Hardness} = 1.37 \text{ N20} - 59.3 \quad (r^2 = 0.997)$$

Figure 1  
Hardness of cocoa butter based systems



### Compound Coatings

A second set of coatings based on both lauric and non-lauric cocoa butter replacers was also evaluated in the same way. The fat phases of these compound coatings were based on:

- Medium solid fat non-lauric CBR
- 80/20 medium solid fat non-lauric CBR/cocoa butter
- High solid fat non-lauric CBR
- Hardened coconut oil
- Palm kernel stearine
- Hardened palm kernel stearine

The solid fat content at 20°C and the hardness at 20°C are shown in Table 2. Linear regression was used to obtain a statistical correlation between the solid fat content and the hardness. The experimental results and the predicted hardnesses from the linear regression are shown in Figure 2.

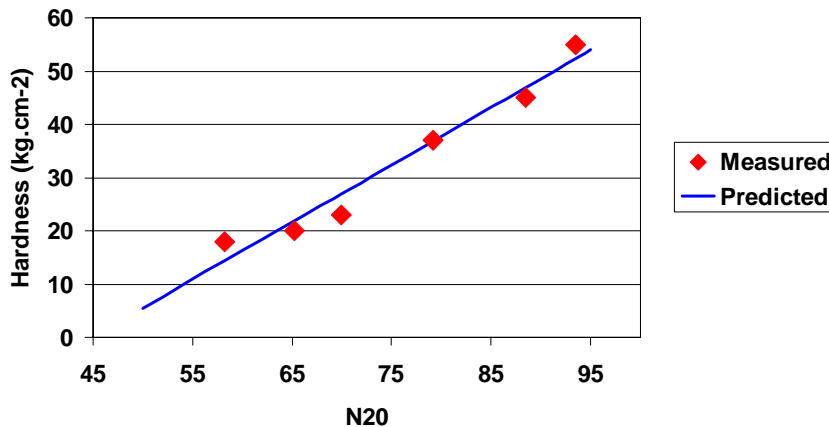
Table 2 Solid fat content and Hardness of compound coatings at 20°C

Fat phase	N20	Actual hardness kg.cm <sup>-2</sup>	Predicted hardness kg.cm <sup>-2</sup>
Medium-solid CBR	69.9	23	26.9
80/20 medium-solid CBR/CB	65.2	20	21.8
High-solid CBR	88.5	45	47.0
Hardened coconut oil	58.2	18	14.3
Palm kernel stearine	79.2	37	36.9
Hardened PK stearine	93.5	55	52.4

The statistical correlation by linear regression gives a 'best fit' relationship of:

$$\text{Hardness} = 1.08 \text{ N20} - 48.6 \quad (r^2 = 0.962)$$

Figure 2  
Hardness of compound based systems



In both systems the correlation between solid fat content and hardness was very good showing that it is indeed possible to predict the hardness of a chocolate or a compound coating from the solid fat content of the fat phase.

However, it is not possible to combine the two types of product and still get a good correlation. When the two groups are combined the best fit equation is:

$$\text{Hardness} = 0.98 \text{ N20} - 37.8 \quad (r^2 = 0.831)$$

It is clear that the correlation coefficient is much lower than those found when each group is treated separately. This is undoubtedly due to the different ways in which a tempered cocoa butter based system and an untempered compound system crystallise.

For a given solid fat level the cocoa butter based products have a greater hardness (see Table 3)

Table 3 Predicted Hardnesses of Chocolate and Compounds with Specific Solid Fat Contents

N20	Hardness Chocolate kg.cm <sup>-2</sup>	Hardness Compound kg.cm <sup>-2</sup>
60%	22.9	16.2
65%	29.8	21.6
70%	36.6	27.0

Whilst there is a good correlation between the solid fat content of the fat phase of a chocolate or compound system and the hardness of that chocolate, two points of caution should perhaps be introduced.

Firstly, the stabilisation given to fats prior to measuring their solid fat contents can affect the measured values. This is particularly the case with polymorphic cocoa butter-rich fat phases. Whilst there will be a correlation between hardness and solid fat content irrespective of how the fat phase is stabilised any specific correlation equation will only apply to systems stabilised in the same way as the systems used to define that equation.

Secondly, although the solid fat content is probably the most important parameter in defining hardness, the method of producing the chocolate or compound can also potentially have an influence. Of significance in this respect is the particle size distribution. This means that any equation defined is mainly applicable to chocolates produced in the same way.

So what does all this mean for the relevance of the equations quoted earlier? It means that they can be used to give an indication of the hardness of a particular chocolate and they are useful for making relative comparisons between chocolates. However, for an accurate prediction of hardness it will be necessary to first construct an equation from measurements on model systems using (a) the normal method of producing the chocolate and (b) the normal stabilisation procedure prior to measuring the solid fat content.

Once these equations have been established then a chocolate or compound manufacturer can use them as a predictive tool for estimating the hardness of the product.