ACOUSTIC INVESTIGATION OF CHOCOLATE

Katalin Badakné Kerti [1]*, Viktória Zsom-Muha [2], Tamás Zsom [3], Dávid Nagy [2], József Felföldi [2]

Abstract

In our experiments, the sound generated during the breaking of chocolate samples was examined by acoustic method. The fracture was performed by a precision penetrometer, the breaking sound was recorded. Texture index (TI) was calculated from the resulting signal. In the first experiment, the change of the resulting TI was monitored as a function of the samples temperature. To this, the chocolate samples were cooled (8-10 °C) and then rewarmed at room temperature for different time periods. Based on the results, the individual temperature groups were completely separated from each other, but we did not find a trend to describe the change. In the other experiment, we investigated whether the different cocoa-containing samples can be distinguished based on the acoustic signal obtained. For this experiment we used 6 dark and 2 milk chocolate varieties with 20 samples per group. Based on the TI, we could identify and classify the chocolate samples in the appropriate groups (based on cocoa content). According to linear discriminant analyses chocolates with different cocoa content were completely separated and showed a certain pattern. There are three directions, which divides our data into three groups: Group 1: milk chocolate (40%, 45% cocoa content), Group 2: dark chocolates with 54-65% cocoa content, Group 3: dark chocolates with 70-85% cocoa content. Based on the obtained results, it can be stated that the type of chocolate can be determined on the basis of TI obtained by acoustic method. The method is promising, but further experiments are needed.

Keywords: acoustic method, chocolate, texture index

Introduction

The food consumed in our meals is experienced with all our senses. A lot of food gives a certain sound when consuming it. The idea that sound sensation plays an important role in the perception of textures was first published by Drake (1963), thereby promoting food texture

Szent István University, Faculty of Food Science, [1]Department of Grain and and Industrial Plant Processing, [2]Department of Physics and Control, [3]Department of Postharvest Science and Sensory Evaluation

*e-mail: badakne.dr.kerti.katalin@etk.szie.hu

analysis. If a crunchy product does not cause the expected sound after the bite, it can be attributed to the texture, the poor quality or inadequate components or process. Wójtowicz et al. (2015) investigated the effect of various recipes and processing conditions of breakfast cereals on the finished product. From the results obtained, the appropriate manufacturing technology was determined. In their study, Salvador et al. (2009) concluded that the force / deformation test and the acoustic information received at the same time could be an effective tool for comparing sensory results in crisp products. Mohamed et al. (1982) also demonstrated in their study of different waffles for different influences that there is a significant correlation between sensorial sound characteristics and instrumental measurements ($r = 0.701$). Vickers (1987) found that combinations of acoustic and mechanical tests describe food sounds better than any technique alone. Two main approaches are used to test the fracture's sound, either the amplitude-time curve of the acoustic signal (Jakuvczyk et al., 2017, Gondek et al., 2013, Salvador et al., 2009) or the amplitude frequency curve is taken up and is used for further analyses. Using a microphone Jakuvczyk et al. (2017) tested various coated and / or stuffed extruded products. The force/deformation test was performed with a TA-HD plus texture analyser. In the experiments of Taniwaki and Sakurai (2008), the food structure was quantitatively evaluated based on the Texture Index (TI), which is defined as energy density.

In our work, we aimed at compiling a mechanical-acoustic method suitable for examining chocolate products. Further objective was to investigate the effect of the sample temperature during the test and the effect of the chocolate cocoa content on the resulting sound response in dark chocolate and milk chocolate samples.

Materials and methods

For the temperature-dependence tests, 50% cocoa containing dark chocolate by Fin Carre was used. Chocolate samples were placed in a fridge for 1 hour. Then, the temperature of 8 samples was measured every 3 minutes with an infrared thermometer and the acoustic response of their breaking was recorded, and the remaining samples were measured in every 5 minutes. Three parallel measurements were made on the same batch of chocolates (a total of 39 samples). From the measured temperatures, 6 temperature groups were formed (Group 1 - 8-10 ° C, Group 2 - 10.1-13 ° C, Group 3 - 13.1-16 ° C, Group 4 - 16.1 -19 ° C, Group 5 - 19.1-22 ° C, Group 6 - 22.1-25 ° C), in which samples were classified.

For the cocoa content test, samples were provided by Interfood & Pharma Kft. The chocolates were of the same shape, with varying cocoa contents, 20 samples for each cocoa content were

tested. Chocolate cubes were placed in a fridge for one day before the acoustic tests and their temperature were recorded directly before measuring. 6 types of dark chocolate and 2 types of milk chocolate were examined (a total of 160 samples). The list of different types and cocoa contents of the chocolates is shown in Table 1.

Name	Cocoa content (%)	Fat content (%)	Type	Description
Santander	85	48 – 52	Dark	Single Origin Chocolate
Peru	72	41 – 45	Dark	Single Origin Chocolate
Arauca	70	41 – 44	Dark	Single Origin Chocolate
Huila	65	36 – 39	Dark	Single Origin Chocolate
Macondo	60	34 – 37	Dark	Casa Luker Cacao
Sombra	54	-	Dark	Casa Luker Cacao
Colombia	45	-	Milk	Single Origin Chocolate
Noche	40	-	Milk	Casa Luker Cacao

Table 1: Chocolate samples

The sound of the chocolate breaking was recorded using a microphone in the set up shown in Figure 1 and recorded with a "WavePad" program (WavePad Sound Editor v 5.02, NCH Software) at 44.1 kHz sampling frequency. The chocolate pieces were supported by a ring-shaped sample holder. For the breaking SMS XT-2A Precision Penetrometer (by Stable Microsystems Ltd.) with spherical probe was used, penetration depth was 7 mm and the rate of speed was 1 mm / s. Then the data from the scanned signal were normalized to always be between -1 and 1, and then they were analysed using the Fast Fourier Transform (FFT). The frequency-domain data (20 Hz-20 kHz range) were then sub-divided into third-octave intervals and the Texture Index (TI) was calculated for each frequency band:

$$TI = (f_L \cdot f_H)^{\frac{1}{n}} \sum_{i=1}^{n} V_i^2$$

where

- f_L represents the lowest and f_H the highest frequency of each frequency band (third-octave intervals);

- V_i is the amplitude of the texture signal, and
- n is the number of data points in the given frequency band

The processing of the signal and the calculation of the "texture index" were done in the Mathcad program based on the algorithm developed by the Department of Physics and Control, SZIU. In further analyses this parameter was used to characterize the acoustic response of the chocolate's fractioning.
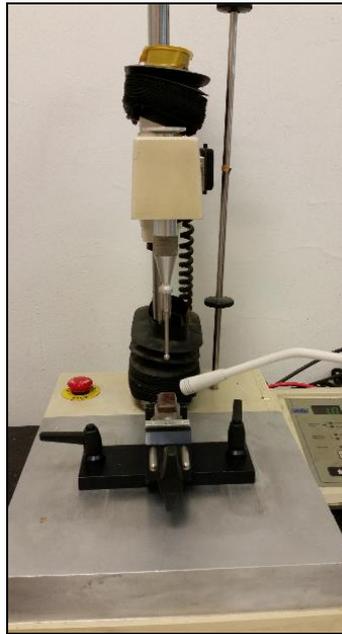
Figure 1. Set up of the acoustic measurements using SMS XT-2A

The statistical analyses of the data were performed by using Rstudio (R-project 3.4.1) statistical program. PLSR (partial least squares regression) analysis was used to find the correlation between the cocoa content and the frequency. Linear Discrimination Analysis (LDA) was applied to separate groups in the various measurements for acoustic sound characteristics.

Results and discussion

In the first experiment, the effect of the temperature on the acoustic response of chocolate fractioning was investigated. On the basis of our results, samples in the higher temperature groups got higher "texture index" values. Linear discrimination analysis (LDA) showed clearly (Fig. 2) that chocolate samples of different temperature groups could be distinguished by their sound signal. However, we did not find a model which could describe consequently the change in the acoustic signal and the temperature.

In the second experiment, different cocoa-containing samples were tested for acoustic sound response. Using the results obtained by the acoustic measurements and the calculated texture index we were able to identify and classify the chocolate samples corresponding to their cocoa content with 100% certainty. The Linear Discrimination Analysis (LDA) diagram (Figure 3) illustrates well that different chocolate cocoa-containing chocolates are nicely separated from each other and even show some pattern.
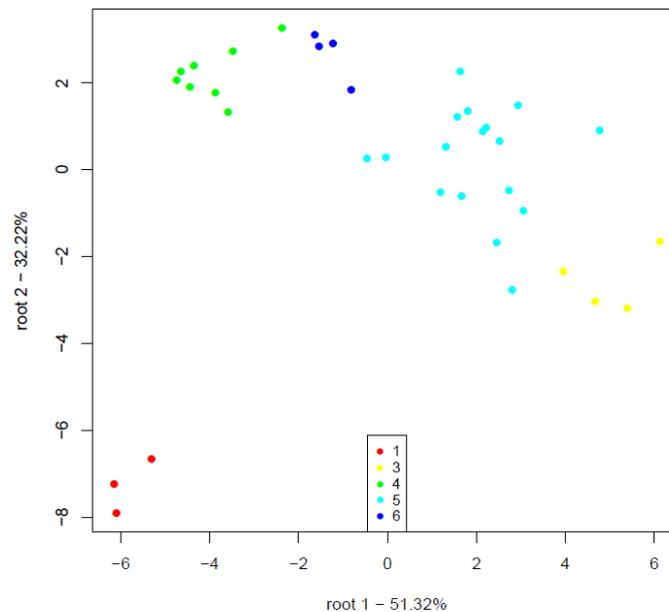
Figure 2: LDA analysis of the acoustic responses of chocolate samples at different temperatures (Group 1 - 8-10 ° C, Group 2 - 10.1-13 ° C, Group 3 - 13.1-16 ° C, Group 4 - 16.1 -19 ° C, Group 5 - 19.1-22 ° C, Group 6 - 22.1-25 ° C)

The separation of first group (milk chocolates) is obvious because their composition differs significantly from dark chocolates, as they contain milk, which softens their texture and are therefore more flexible. Both hardness and flexibility are of great significance to the sound intensity of the chocolates, as if energy is released quickly, high intensity sounds will be generated. Thus, the hard texture with low degree of flexibility (less elastic) is more likely to provide rapid release after breaking and thus high intensity sound output. The more elastic nature, allows greater deformation of the samples throughout the break, resulting in slower energy release (Gregerson et al., 2015).

There are three directions for the growth of the cocoa content, which divides our data into three groups: group 1: milk chocolate (40%, 45% cocoa content), group 2: chocolates with 54-65% cocoa content, group 3: dark chocolate with 70-85% cocoa content.
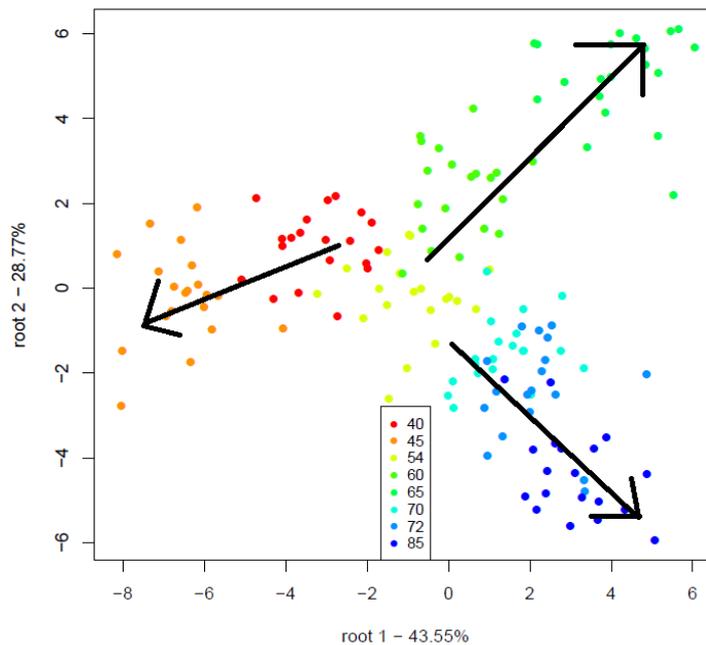
Figure 3: LDA analysis of the „texture index" of different cocoa containing chocolate samples (numbers are confirming the cocoa content of the samples)

We do not know exactly the reason for the difference between Group 2 and Group 3. There is no information about the exact composition of the samples; but since the fat composition of cocoa beans grown at different locations may differ, which affects the properties of the chocolates. PLSR test was performed, the results of which are shown in Figure 4. Separately, PLSR was performed only on the dark chocolate groups (Figure 4a) and on all samples used for the cocoa content test (Figure 4b). In both cases, a linear relationship was found between the cocoa content and the sound response of the breaking.

The frequency at which the largest value of the regression vector was given was 68 Hz for only dark chocolates and 217 Hz for all chocolate samples together. All chocolate samples analysed together gave a higher R^2 value (0.8397) and validation was also better ($R^2 = 0.7218$) than when only the dark chocolate samples were analysed. There is in any case a close relationship between the cocoa content and the crispness of the chocolate samples, which should be taken care of, as the sound released during breakage plays an important role in consumer perceptions of different food products, especially for chocolate.
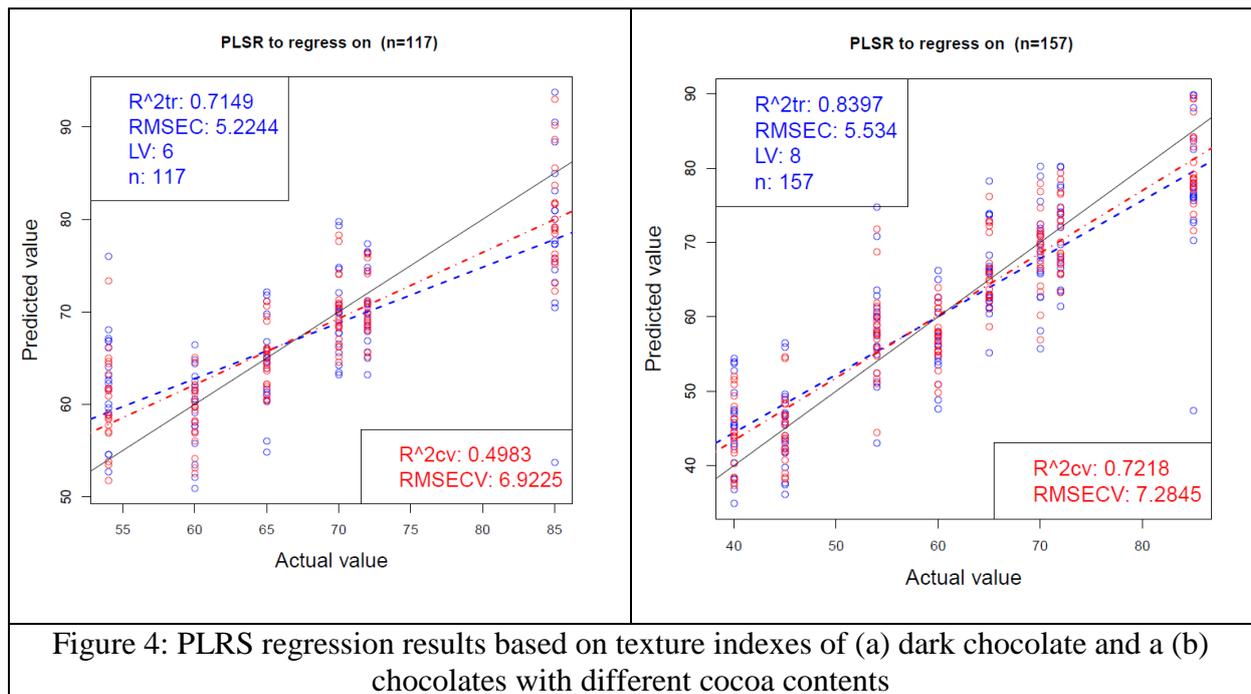
Figure 4: PLRS regression results based on texture indexes of (a) dark chocolate and a (b) chocolates with different cocoa contents

Conclusions

Breaking sound of chocolate is an important parameter for judging the eating experience. A well-tempered, high cocoa containing chocolate expected to break with a snap.

From our experiments we can conclude that measuring the acoustic signal of chocolates' breaking is suitable for testing the chocolates' texture. With the help of calculated texture index, sample groups of different temperatures could be distinguished, but we did not find a trend that describes the change.

Using texture index (based on the acoustic response values) we could identify the chocolate samples in the corresponding cocoa-containing group 100% correctly.

Linear discriminant analyses distinguished among different chocolate samples based on their cocoa content and a certain pattern was recognisable. There were three directions according to the cocoa content, which divided our data into three groups. Group 1: milk chocolates (40%, 45% cocoa content), Group 2: chocolates with 54-65% cocoa content, and Group 3: dark chocolates with 70-85% cocoa content.

Using acoustic response, a quick method for estimating the cocoa content of chocolate could be established, with suitable equipment and the support of a statistical analysis program. This new method wouldn't require any sample preparation, and was based on purely physical parameters instead of chemical characteristics.

References

1. Drake, B. K. (1963): Food Crushing Sounds. An Introductory Study. *Journal of Food Science*. 28 (2): 233-241

2. Gondek, E., Jakubczyk, E., Herremans, E., Verlinden, B., Hertog, M., Vandendriessche, T., Verboven, P., Bongaers, A.A.E., Estrade, P., Nicolaï, B.M. (2013): Acoustic, mechanical and microstructural properties of extruded crisp bread. *Journal of Cereal Science.* 58 (1): 132-139

3. Gondek, E., Jakubczyk, E., Herremans, E., Verlinden, B., Hertog, M., Vandendriessche, T., Verboven, P., Bongaers, A.A.E., Estrade, P., Nicolaï, B.M. (2013): Acoustic, mechanical and microstructural properties of extruded crisp bread. *Journal of Cereal Science*. 58 (1): 132-139

4. Gregerson, S.B., Povey, M.J.W., Kidmose, U., Andersen, M.D., Hammershøj, M., Wiking, L. (2015): Identification of important mechanical and acoustic parameters for the sensory quality of cocoa butter alternatives. *Food Research International*. 76: 637–644

5. Jakubczyk, E., Gondek, E., Tryzno, E. (2017): Application of novel acoustic measurement techniques for texture analysis of co-extruded snacks. *LWT - Food Science and Technology*. 75: 582-589

6. Mohamed, A.A.A., Jowitt, R., Brennan, J.G (1982): Instrumental and sensory evalutaion of crispness: I – In friable foods. *Journal of Food Engineering.* 1: 55-75

7. Salvador, A., Varela, P., Sanz, T., Fiszman, S.M. (2009): Understanding potato chips crispy texture by simultaneous fracture and acoustic measurements, and sensory analysis. *LWT - Food Science and Technology*. 42 : 763–767

8. Vickers, Z.M., Bourne, M.C. (1976): A Psychoacoustical Theory of Crispness. *Journal of Food Science.* 41: 1158–1164

9. Wójtowicz, A., Mitrus,M., Oniszczuk, T., Mościcki, L., Kręcisz, M., Oniszczuk, A. (2015): Selected physical properties, texture and sensory characteristics of extruded breakfast cereals based on whole grain wheat flour. *Agriculture and Agricultural Science Procedia*. 7: 301 – 308