https://doi.org/10.17221/225/2020-CJFS

Homogeneity of the selected food mixes

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Citation: Matuszek D.B., Bierczyński K., Jędrysiak A., Kraszewska A. (2021): Homogeneity of the selected food mixes. Czech J. Food Sci., 39: 197–207.

Abstract: The article presents the results of homogeneity assessments for selected food mixes based on computer image analysis. The study was conducted on müsli and condiment mixes standardly available on the consumer market. A total of 40 different ready-for-use products were analysed. Collected samples from three package of each product were placed in a special chamber and then photographed. Photographs were then subjected to computer image analysis to acquire information on the percentage content of individual components. Homogeneity assessment was based on the contents of a selected component called tracer and the coefficient of variation (*CV*). Lower *CV* values (3.02–27.31%) and thus better homogeneity was observed for condiment mixes as compared to müsli mixes (3.57–59.15%). Fourteen of twenty condiment mixes had adequate (acceptable at *CV* ≤ 10%) mixing degree. For the müsli, only six of the tested mixes had appropriate homogeneity. The presented results are a preliminary to developing an image-based methodology for determining the uniformity of granular dry food mixes.

Keywords: granular mixtures; müsli; condiment; computer image analysis; coefficient of variation

Mixing is one of the key processes determining the quality of the final product. It is used in numerous industries, including the food industry. In food production, mixing is used as a means to homogenise ingredient and product composition, to intensify heat or mass exchange processes, or to accelerate certain chemical and biochemical processes. Mixing consists of two or more components of different shapes and dimensions being combined to form a mixture with a homogeneous concentration of all components (Harnby et al. 1992; Bridgwater 2012). Food mixtures are present in everyday life and have many uses (e.g. spices, flours, coffee, dyes, dry drinks, cakes, müsli, etc.) (Cuq et al. 2013). In this study, it was decided to analyse the homogeneity of two types of food mixes: müsli and condiment mixes as commonly available products and often chosen by consumers (Fast and Caldwell 2000; Shenoy et al. 2014).

Cereals ready-to-eat (RTE) originated in the United States in the latter part of the 19th century. The assortment of cereal flakes available on the consumer market is very diverse; due to the significant diversity of ingredients and production methods, the products differ

https://doi.org/10.17221/225/2020-CJFS

in taste, appearance, and nutritional value. All these qualitative determinants are influenced by the appropriate mixing of components. Usually, cereal flakes are consumed together with dairy products such as milk, yoghurt, or kefir (Fast and Caldwell 2000). Mixes of cereal flakes (wheat, oat, rye, barley) with nuts, seeds, and lyophilised, dried, or candied fruit are referred to as müsli mixes (Kołożyn-Krajewska and Sikora 1997). The additives are responsible for different gustatory and nutritional properties of mixes. They are also responsible for the homogeneity of mixes. Due to the complexity of müsli mixes, it is quite difficult to ensure appropriate quality and homogeneity of these types of products (Gondek and Lewicki 2008). Condiments are compounds containing one or more spices or spice extract (Peter 2012). Condiment mixes are available either as ground mixes or as whole-grain mixes. Preparation of condiments consists of cleaning, drying, grinding, and sieving the starting materials; in the case of condiment mixes, the mixing step is also involved (Bandara et al. 2015). The purpose of mixing is to obtain a product whose ingredients look attractive even in transparent packages. Varying the composition and uniformity of the product in the package is highly undesirable (Cuq et al. 2013).

The scale of scrutiny of the mixing process in the food industry is most often about determining whether the final mixture can be considered homogeneous or not. Even after a satisfactory degree of homogeneity is achieved at a certain point, secondary segregation of ingredients may occur upon storage. This often happens when the mixture contains several different components or phases. It should be crucial for the processor to ensure that the product maintains homogeneity when reached on the consumer table (Gondek and Lewicki 2008).

It is more difficult to achieve appropriate homogeneity of whole-grain mixes when the mixed ingredients differ in physical parameters such as density, moisture content, or repose angle (Boss 1987). According to many authors, particle size is of the greatest importance, as the variation in particle sizes is responsible for segregation processes (Harnby et al. 1992; Alexander et al. 2003; Yang 2006). Complete mixing of solids is achieved after the mixture has reached the equilibrium state in which the composition of individual samples remains identical throughout the bulk of the product. Segregation occurs when non-homogeneous ingredients are mixed. In such cases, the final mix is characterised by diverse homogeneity, possibly far from complete mixing status (Hajduk 2001). A mixture can be considered homogeneous when the probability of finding a given component is the same at all points of this mixture. The state when the grain system of the mixture is completely arranged and unchanging over time is called the perfect state. Therefore, mixing granular materials results in a product that, to a degree, deviates from the state of homogeneity (Boss 1987). In addition, the degree of homogeneity required may vary depending on the application of the particular product. Due to the variety of food mixtures (especially ingredients), there is no single methodology or analytical technique to measure homogeneity (Cuq et al. 2013).

Studies assessing the mixing degree of non-homogeneous granular ingredients have been conducted for many years. The research on novel methods and tools for the assessment of the behaviour of components during the mixing processes is being continued. Methods based on image analysis of mixtures are most commonly used (Boss et al. 2002; Realpe and Velasquez 2003; Daumann and Nirschl 2008; Matuszek 2015; Matuszek and Królczyk 2021). A solution of this type was also used to assess the percentage share of tracer in condiment and müsli mixes in this study. The authors decided to carry out tests on ready-for-use commercial products, those that go directly to the consumer. The aim of the study was to assess the homogeneity of granular dry food mixes, which often ends on the consumers' table. The right level of mixing degree affects the quality of the product. Each portion of the product should have a composition declared by the producer. In this work, homogeneity referred to the uniformity of the tracer's share in the mixes by analysing its content in the samples. A high-quality mixture will show very little variation in composition between samples (Harnby et al. 1992). Determination of the share of each component (in multi-component granular mixtures) is very time consuming and often even impossible, which is why indicator methods are used in practice. Tracer can be a selected component of the mixture (selected grain, raw material or active substance such as carbonate, enzymes, and others depending on the type and purpose of the mixture) or a component intentionally added into it, e.g. Microtracer iron filings or Microgrids crushed corn grains (Eisenberg and Eisenberg 1992; Zawiślak et al. 2011; Królczyk 2014). Depending on the type of key component, its content is marked differently. Presented work uses computer image analysis, which is why in each mix, the tracer with intense colouring (easy to pick up on the background of a multi-coloured sample) was marked. Based on its contribution, the homogeneity of the mixture was then determined. It may

https://doi.org/10.17221/225/2020-CJFS

be debatable whether this procedure is correct; however, in the case of such different and multi-component mixtures, there is no developed solution or reference method. In addition, the usefulness of the tool used (computer image analysis) to assess the quality of granular mixtures has been described and proved in numerous scientific studies (Muerza et al. 2002; Realpe and Velasquez 2003; Królczyk 2014; Matuszek and Królczyk 2021). Therefore, based on experience and available literature (presented in this part), it was assumed that the proposed methodology allows determining the quality of mixtures in terms of their homogeneity. The features of the method, such as the speed of the analysis, the ease of its implementation without the need for highly specialised equipment, can be used by quality control units or production facility for this type of mixtures.

MATERIAL AND METHODS

The tests were carried out on 40 dry granular mixtures: 20 vegetable/herbal mixes (condiment mixes) and 20 müsli mixes. Three packages (from the same batch) of each product were purchased. Therefore, the homogeneity of mixtures in 120 packages was analysed.

The numbers and types of the components varied between individual products (Table 1 and 2).

Müsli mixes consisted of components like various types of cereal flakes, whole nuts or nut crumbs, and dried, candied, or freeze-dried fruit on the one hand, and additives such as aromas, salt, or inulin, on the other hand (Table 1). The vegetable/herbal mixes consisted of components like different types of salt, pepper, and dried powdered vegetables such as paprika, carrot, celery, parsnip, whole mustard seeds, and dried herbs (Table 2). The homogeneity of multi-component granular dry mixtures can be determined based on the content of the tracer. Thus, the tracer represents the other ingredients of the mixture. A tracer cannot be a major ingredient of the mixture (exception: if there are only major components in the mixture), but on the other hand, it must be easily analysed (Lamotte 2018). Tables 1 and 2 indicate (blue) which of the components of the mixture was selected as the tracer.

Table 1. Number and type of components in tested müsli mixes

Type of component	Mix No.																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Oat flakes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X	X
Wheat flakes	X	X	–	X	–	–	X	X	–	–	X	X	–	–	–	–	–	–	–	X
Rye flakes	–	X	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	X
Spelled flakes	–		–	–	X	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–
Corn flakes	–	X	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	X	–	–
Barley flakes	–	–	X	X	X	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–
Buckwheat flakes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–
Millet flakes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X
Sugar	X	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–
Palm oil	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Glucose-fructose syrup	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sodium carbonates	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Burnt sugar	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aroma	X	–	–	–	X	X	–	–	X	X	–	–	–	–	–	–	–	–	–	–
Raisins	X	X	X	X	X	X	X	–	–	–	X	X	X	–	–	X	–	–	–	–
Dates	X	X	X	X	–	–	–	X	–	–	–	–	–	–	X	–	X	–	–	–
Pears	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Apples	X	X	–	–	X	X	–	X	–	–	–	–	X	–	–	–	–	–	–	–
Coconut	X	–	X	X	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	X
Rice flour	X	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–
Banana chips	–	X	X	X	–	–	–	–	–	–	–	–	–	–	X	X	X	–	–	–

https://doi.org/10.17221/225/2020-CJFS

Table 1. to be continued

Type of component	Mix No.																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Apricots	–	X	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	X	–
Peaches	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–
Figs	–	X	–	–	–	–	–	X	–	–	–	–	–	–	X	–	–	–	–	–
Plums	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Linseed	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sunflowers seeds	–	X	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	X	–	–
Hazelnuts	–	X	X	X	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	X
Candied pineapple	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Candied papaya	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pumpkin seeds	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Almonds	–	–	X	X	–	–	–	–	–	–	–	–	–	–	X			X		
Pecans	–	–	X	X	–	–	–	–	–	–	–	–	–	–						
Inulin	–	–	–	–	X	X			–								X			
Gelatin blueberry	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Goji barriers	–	–	–	–		X	–	–	–	–	X	–	–	–	–	X	–	–	X	–
Freeze-dried berry	–	–	–	–	–	–	–	X	–	X	–	–	–	–	–	–	–	–	–	–
Freeze-dried blackberries	–	–	–	–	–	–	–	X	–	X	–	–	–	–	–	–	–	–	–	–
Freeze-dried raspberries	–	–	–	–	–	–	–	X	X	X	–	–	–	X	–	–	–	–	–	–
Skimmed milk powder	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–
Freeze-dried strawberry	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	–	–	X	–	X
Freeze-dried currant	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	X	X	–
Salt	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–
Red beet juice	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–
Citric acid	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–
Amaranth popping	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	X	–
Cranberry	–	–	–	–	–	–	–	–	X	X	X	X	–	–	–	–	–	–	–	–
White chocolate	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–
Sesame seeds	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–
Peanuts	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–
Soy crisps	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–
Pumpkin seeds	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	X	–
Hemp seeds	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–
Chia seeds	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		X	–
Number of components	14	16	12	13	8	8	4	11	8	14	8	6	5	4	7	7	4	6	9	7

Blue – tracer; X – component is present

https://doi.org/10.17221/225/2020-CJFS

Table 2. Number and type of components in tested condiment mixes

Type of component	Mix No.																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Salt	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	X	–
Himalayan salt	–	–	–	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–
Sea salt	–	–	–	–	–	X	–	–	–	X	–	–	–	–	–	–	–	–	–	–
Sugar	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	X	–
Chili	X	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	X	–	X
Red pepper	–	X	–	X	–	X	–	–	–	X	–	–	X	–	–	X	–	–	–	–
Black pepper	X	–	X	X	–	–	–	–	–	X	–	X	X	–	–	X	X	X	–	–
Green pepper	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–
White pepper	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–
Lemon peel	–	–	X		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
White mustard	–	–	–	X	–	X	–	–	–	X	–	–	X	–	–	–	–	–	–	–
Black mustard	–	–	–	–	–	X	–	–	–	X	–	–	–	–	–	–	–	–	–	–
Carrot	–	X	–	–	X	–	X	X	–	–	X	X	X	–	X	–	X	–	X	–
Parsley	–	X	–	–	X	–	X	X	–	–	X	X	–	–	X	–	X	–	X	X
Leek	–	X	–	–	X	–	–	X	–	–	X	X	–	–	X	–	X	–	–	–
Onion	–	X	–	–	–	–	X	X	–	X	X	X	–	–	–	–	X	–	X	–
Red onion	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Garlic	–	X	–	X	–	–	–	–	X	–	–	–	–	X	–	–	–	–	X	X
Coriander	–	–	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lemongrass	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cumin	–	–	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	X	–	–
Parsnip	–	–	–	–	X	–	X	X	–	–	–	–	–	–	X	–	–	–	–	–
Lovage	–	–	–	–	X	–	–	–	–	–	–	X	–	–	–	–	X	–	X	–
Fenugreek	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cinnamon	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fennel	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cloves	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Turmeric	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	X	–	–	–
Cardamom	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Celery	–	–	–	–	–	–	–	X	–		X	X	–	–	X	–	–	–	–	–
Dried tomatoes	–	–	–	–	–	–	–	–	X	–	–	–	–	X	–	–	–	–	–	–
Basil	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	X
Savoury	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–
Allspice	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	X	X	–	–
Thyme	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–
Bay leaf	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	X	–	–	–
Dill	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	X	–
Sesame	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–
Black seeds	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–
Corn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–
Rosemary	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	–	–
Number of components	3	7	3	8	7	13	5	6	3	8	5	11	5	3	5	4	13	5	8	4

Blue – tracer; X – component is present

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The tests were carried out in laboratory conditions. Three mix samples were taken from each package (from three parts of each box: upper, middle, bottom) delivered to the laboratory. The mass of samples was: 15 g for müsli, 6 g for condiment mixes. A total of 360 samples (three from each package) were therefore tested.

Each sample was weighed using laboratory scales with 0.01 g accuracy (AD200; Axis, Poland). Next, the samples were placed on Petri dishes (120 × 20 mm) and transferred into the photo chamber for image acquisition (Figure 1).

The proprietary photo chamber facilitated the elimination of external factors potentially affecting the quality of images. Repeatability and reliability of image acquisition required the maintenance of strict assessment conditions. The samples were illuminated from above and below (illuminated tabletop). It was observed that the lighting of the sample allowed for a clearer extraction of the ingredient, which was characterised by an intense and clearly different colour than the other ingredients, such as raisins against a mixture of müsli or carrots against a mixture of vegetables. These observers were then used to select a tracer for a given food mixture (Table 1 and 2). The camera lens was located at the central upper part of the chamber. Pictures with a resolution of 1600 × 1200 pixels were obtained with a digital camera [standard lens, 20.1 Mpix resolution, 35 mm focal length, +1.3 exposure value (EV)]. The stand is equipped with Patan® 1.0.0.0 (by Krótkiewicz) computer image analysis software. The analysed images were recorded in the bitmap (BMP) format. Each pixel was assigned a three-element vector of numbers represented in the RGB – 256 system. The examined range of presented images indicates the colours responsible for the key component and the background. In the image in the BMP record, fragments appropriate for the analysed components (three classes) were indicated, the areas marked in this way obtained values in the RGB scale. Computer image analysis describes the sum of surfaces, conducted according to morphological analysis, belonging to the class "tracer" in relation to the total area. Three classes of areas were identified within the analysed images: that of the key ingredient, i.e. tracer (1), and those of the background (2 and 3). The designation of the two classes defining the background was due to the multi-colour of the sample (Matuszek and Królczyk 2021). Based on the computer analysis of the image, the percentage shares of each class were obtained, but for the calculation of coefficient of variation (*CV*), only the share of tracer was used. These settings have not been changed for samples taken from a given package. Changes were made at the time of the analysis of images representing various food mixtures, i.e. areas representing each of the three classes were again indicated. In each mixes the tracer (key component) was identified. The error of the computer analysis of the image in the class determining (1, 2, and 3, mentioned above) and measuring of the surface is at a very low level (from 5.2×10^{-8} to 5.9×10^{-8}), so it can be omitted (Matuszek and Wojtkiewicz 2018). However, the precision compared to the control method was determined at a high level and proved by Matuszek and Królczyk (2021). As presented earlier, the main guideline for the tracer was its colour. Moreover, if possible, the same tracer was set for as many mixtures as possible. As can be seen in Table 2, in the case of spice mixes, a carrot was most often marked as the key component. However, in the case of müsli mixes, the required guidelines were most often obtained for raisins (Table 1). After the computer image analysis starts, the percentage contents were determined for all classes of areas (Figures 2 and 3).

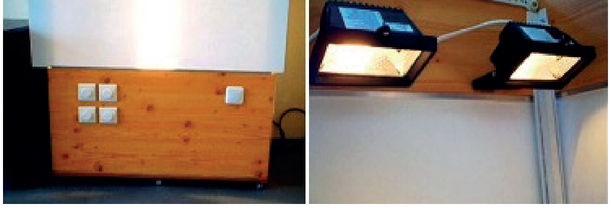

Figure 1. Test station – image acquisition chamber (Szwedziak and Krótkiewicz 2006)

For the calculations, only the share of tracer [mean from three samples and three packages and standard deviation (SD)] was taken. In order to find out how good the mixture is, the *CV* (100 × SD/mean) was used. The state of the composition of granular mixtures can be represented by means of SD, calculated on the basis of the analysis of the composition of the samples, in this case, the content of the tracer in the samples. In the case of multi-component mixtures, most often uses the indirect method based on determining the share of the key component (tracer) (Eisenberg 2008; Asachi et al. 2018; Matuszek and Królczyk 2021). Determining the share of each component in granular mixtures, if possible, is very time-consuming because, in the case of multi-component mixture, it involves manual separation (Królczyk 2016). However, in the case of mixtures characterised by considerable differentiation in terms of the characteristics of their components (such as additives in the form of powders), such assessment (the share of each component) is sim-

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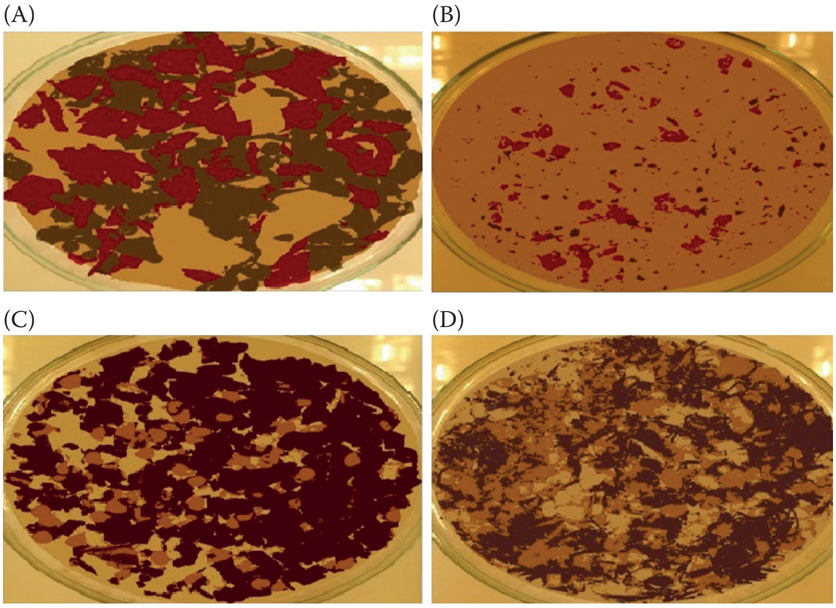

Figure 2. Photographs of selected condiment mix samples subjected to computer image analysis; (A) mix No. 9, (B) mix No. 10, (C) mix No. 13, (D) mix No. 12

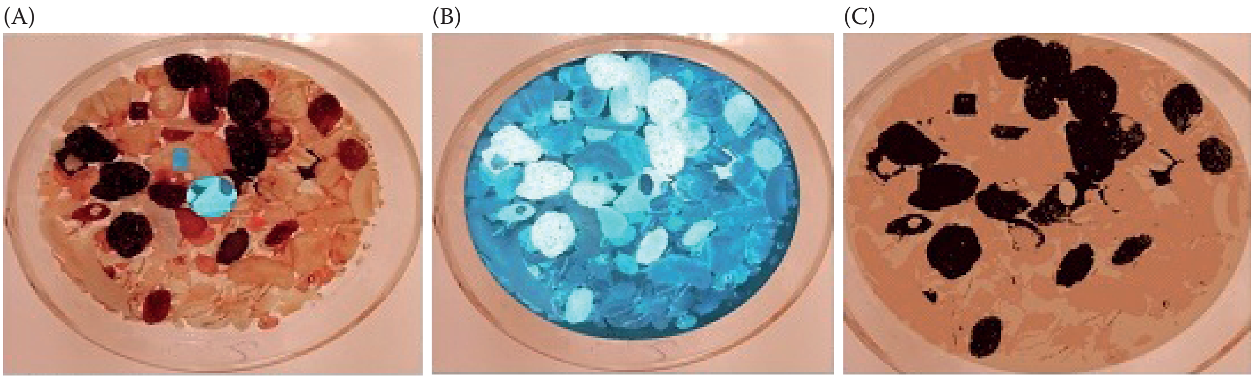

Figure 3. Photographs of selected müsli mix samples (A) before, (B) during, and (C) after computer image analysis

ply impossible. The *CV* values change from 0% to 100%. Assessment of the state of deviation of a mixed system from a certain ideal state (*CV* = 0%) can be a measure of homogeneity. In this state, in each taken sample, there is exactly the same share of the key component. Higher *CV* values indicate a worse homogeneity of the mixture, i.e. greater variability of the tracer's contribution to the samples. In this study (due to the lack of official guidelines), it was assumed that the *CV* ≤ 10% value is responsible for good (acceptable) quality (homogeneity) of the mixture (Kwiatek and Przeniosło-Siwczyńska 2007; Cuq et al. 2013; Shenoy et al. 2015).

RESULTS AND DISCUSSION

The results of homogeneity assessments for the tested food mixes are presented in Tables 3 and 4 and in respective graphs (Figures 4 and 5).

As revealed by the analysis of the results, lower *CV* values (average from three mixes: min. 4.00%, max. 23.50%, and SD = 5.11) were observed for condiment mixes (Table 3, Figure 4). For this class of mixes, the lowest *CV* of 3.02% was determined for mix No. 9 and the highest *CV* of 27.31% was determined for mix No. 3. The mean coefficients for these mixtures amounted to 4.0% and 23.5%, respectively. For fourteen mixes (70% of tested condiment mixes), mean variation was at the level of *CV* ≤ 10% indicating appropriate mixing. The highest share of results (57%) was obtained for the *CV* range > 5% and ≤ 10%. Much higher *CV* values were observed for müsli mixes (average from three mixes: min. 4.94%, max. 53.16%, and SD = 13.00; Table 4, Figure 5). Only six of twenty mixes (30% of tested müsli mixes) presented with satisfactory homogeneity levels (*CV* ≤ 10%). The lowest *CV*, amounting to 3.57%, was observed for mix No. 3 (mean of three packages 4.94%) while the highest value of 59.15% was observed for mix No. 1 (mean of three packages 53.16%). The highest share of the results (30%) was obtained for the *CV* in the range > 10 and ≤ 15%. In addition,

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Table 3. Results of homogeneity assessments for the tested condiment mixes (n = 180)

Mix No.	*CV* (%)*			Mean ± SD (%)
	package 1	package 2	package 3	
1	9.10	11.00	7.20	9.10 ± 1.90
2	5.02	9.00	8.50	7.51 ± 2.17
3	23.21	20.02	27.31	23.50 ± 3.66
4	21.79	18.01	19.00	19.59 ± 1.96
5	4.03	5.10	7.01	5.38 ± 1.50
6	8.56	10.00	6.33	8.29 ± 1.86
7	7.26	5.02	7.90	6.72 ± 1.51
8	16.08	15.00	12.90	14.66 ± 1.62
9	3.87	5.12	3.02	4.00 ± 1.06
10	6.35	7.12	9.02	7.49 ± 1.37
11	10.25	12.01	9.25	10.50 ± 1.40
12	18.29	12.89	14.90	15.36 ± 2.73
13	14.85	15.69	10.48	13.67 ± 2.80
14	6.97	9.65	8.57	8.40 ± 1.35
15	10.24	8.17	7.41	8.61 ± 1.46
16	8.24	5.69	6.97	6.97 ± 1.28
17	10.14	10.01	8.14	9.43 ± 1.12
18	4.58	5.60	6.00	5.39 ± 0.73
19	10.48	9.21	9.12	9.60 ± 0.76
20	6.23	5.85	7.12	6.40 ± 0.65

*averaged for three samples; *CV* – coefficient of variation; SD – standard deviation

Table 4. Results of homogeneity assessments for the tested müsli mixes (n = 180)

Mix No.	*CV* (%)*			Mean ± SD (%)
	package 1	package 2	package 3	
1	59.15	51.12	50.12	53.16 ± 4.95
2	17.23	17.09	13.01	15.78 ± 2.39
3	3.57	4.12	7.13	4.94 ± 1.91
4	13.21	11.02	15.10	13.11 ± 2.04
5	21.94	22.90	18.70	23.18 ± 4.63
6	10.42	9.21	8.81	9.48 ± 0.84
7	20.21	21.90	19.30	20.47 ± 1.32
8	42.23	42.90	38.90	41.34 ± 2.14
9	16.04	13.03	15.91	14.72 ± 1.54
10	43.89	41.00	42.00	42.30 ± 1.47
11	13.25	14.58	18.20	15.34 ± 2.56
12	21.01	17.00	25.30	21.10 ± 4.15
13	12.52	14.08	10.85	12.48 ± 1.62
14	10.04	8.26	8.07	8.79 ± 1.09
15	12.58	10.14	10.78	11.17 ± 1.27
16	6.25	8.24	9.10	7.86 ± 1.46
17	9.17	8.69	10.01	9.29 ± 0.67
18	14.25	12.21	11.85	12.77 ± 1.29
19	24.10	28.14	20.07	24.10 ± 4.04
20	5.48	8.24	8.07	7.26 ± 1.55

*averaged for three samples; *CV* – coefficient of variation; SD – standard deviation

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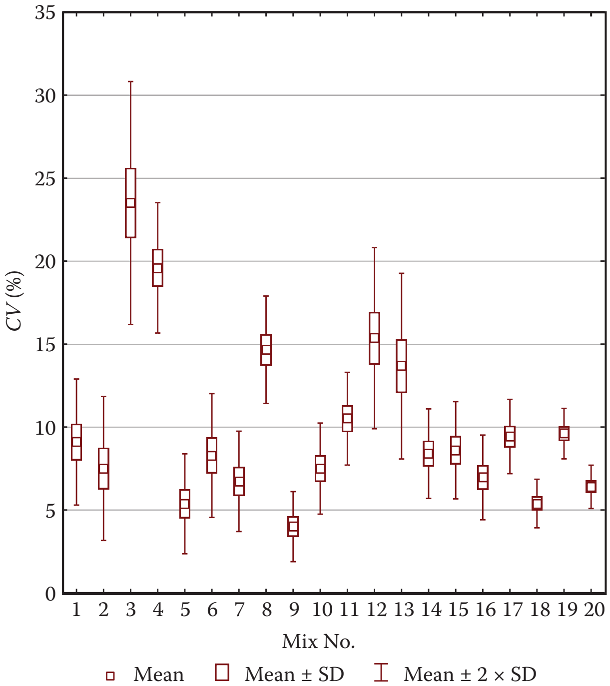

Figure 4. Box plot of the coefficients of variation for different condiment mixes

CV – coefficient of variation; SD – standard deviation

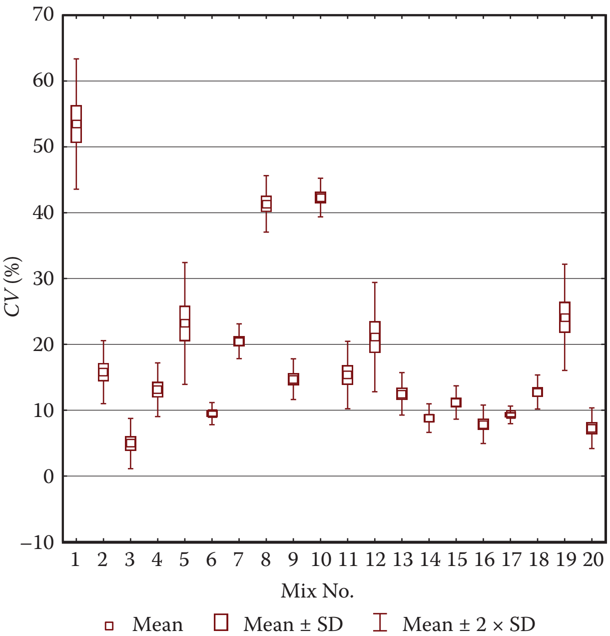

Figure 5. Box plot of the coefficients of variation for different müsli mixes

CV – coefficient of variation; SD – standard deviation

analysis of SD values revealed that the variability of results obtained for condiment mixes was mostly lower than that in the case of müsli mixes. Min.–max. ranges of SD values were 0.65–3.66 for condiments and 0.67–4.95 for müsli mixes, respectively. Interestingly, the lowest and the highest *CV* values in the condiment class were observed for three-component mixes. Condiment mix No. 3 consisted of black pepper (tracer), salt, and chilli flakes, while condiment mix No. 9 consisted of dried tomatoes (tracer), basil, and garlic. One may suspect that this was due to specific properties of the mix components. However, no similar relationship could be observed for the analysed müsli mixes. In this case, the best homogeneity (*CV* = 4.94% ± 1.91) was obtained for a mix consisting of 12 components, whereas the worst homogeneity (*CV* = 53.16% ± 4.94) was obtained for a mix consisting of 14 components. Both compositions included dried and candied fruit, nuts, cereal flakes, and other additives. Raisins were used as the tracer in both mixes. The only difference consisted in part of the cereal flakes is that mix No. 1 is being provided as crunchy aggregates, and no such aggregates are being included in mix No. 3. The presence of larger aggregates might have been responsible for the results. No influence of the number of mix ingredients on the study results was observed either within the product groups or between the product groups. For example, condiment mix No. 6 or No. 17 and müsli mix No. 4 consisted of the same number of components, namely 13 different components. Mean *CV* values for these products were 8.29%, 9.43%, and 13.11%, respectively.

The literature already mentioned refers primarily to research aimed at analysing the mixing process (describing the behaviour of the particles of a mixed system) in laboratory conditions. Some of them refer to the results of tests carried out in industrial conditions. A small workshop concerns the assessment of homogeneity of the final product, packaged in unit packages but still in the production plant. However, there is no research showing how the quality in terms of homogeneity looks at the final stage, i.e. in the hands of the consumer. This is probably due to the multi-faceted aspect of this issue and the multitude of factors that can affect the quality of the mix on the way from the factory to the consumer. Therefore, the results presented in this work are an attempt and a proposal to conduct research in this area. Looking at the results obtained, it seems quite reasonable to shake such products before use (50% of analysed mixes did not have appropriate homogeneity). This can improve their homogeneity. It is also possible that products in the form of granola/cereal bars (bar-shaped, binding by agents like honey and glucose syrup) will be more homogeneous. However, it is worth conducting appropriate tests in this respect.

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The proposed tool allows to determine the share of a component that differs in colour from the background of a multi-component food mixture; therefore, it belongs to the indicator methods. As stated in the works of Shenoy et al. (2014, 2015) in the case of multi-component mixtures (more than two components), image analysis is limited to the assessment of a given component on the surface of the obtained sample and does not allow for an accurate determination of the mixing of each component of the mixture. These tests were carried out on mixtures prepared in laboratory conditions. Currently, there is no tool that would allow estimating the share of all components of multi-component food mixtures. Therefore, the neglected technique (present in this paper) has potential, especially as a method for quick assessment of the quality of finished products in the production facility itself or at the sales stage. In this respect, further tests are required to precisely define the methodology guidelines and the scope of its applicability.

CONCLUSION

Without a doubt, the homogeneity of the product in the form of mixtures available on consumers market requires further studies; all the more so that the availability of relevant literature reports remains limited. The proposed tool (computer image analysis) allows to determine the share of a component that differs in colour (named tracer) from the background of a multi-component food mixture; therefore, it belongs to the indicator methods. The obtained results show that twenty of forty tested food mixes had incorrect uniformity. The obtained degree of homogeneity (*CV* values) for the condiment mixes was in the range of 4.00–23.50% (averaged values). In this case, 70% of tested mixes had a good degree of uniformity. On the other hand, the müsli mixes had worse quality in terms of homogeneity. Only 30% of those mixes had an acceptable degree of mixing ($CV \leq 10\%$). The obtained results were in the range of 4.94–53.16% (averaged values).

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Received: November 9, 2020
Accepted: May 12, 2021