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Techniques to evaluate changes in the nutritional profile of food products

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ABSTRACT

Food products are continuously reformulated by manufacturers; however, the monitoring of chemical compositional changes is rare. The objective of this study was perform a comparative evaluation of the nutritional profile of specific Brazilian food groups from 2003 and 2013 using various methods of analysis. Amounts of carbohydrate, lipid, protein, dietary fiber (DF) and energy were evaluated in 259 products distributed in four food groups. Products from each group were evaluated by percentage change, separated by principal component analysis (PCA) and hierarchical cluster analysis (HCA). Separation was more clearly observed through the use of HCA than PCA. In the majority of the clusters, a significant difference was observed in at least one component. For instance, a large number of products (53%) in the milk group showed a reduction in the amount of lipids, and products in the cereals and meat groups showed increased amounts of DF (55%) and lipids (40%), respectively. Therefore, the joint techniques applied allowed nutrient content differences to be assessed both in a general manner (percentage change) as well as through the identification of the nutrients in foods that had changed significantly. The results emphasized the need for the periodic monitoring of the nutritional profile of foods.

1. Introduction

An increase in the intake of food and constant changes in the formulation of food products has become evident in recent years (IBGE, 2010; Pennington et al., 2007). Manufacturers reformulate food products to improve the nutritional quality (Nijman et al., 2007), to adjust products to adhere to changes in the applicable legislation (Mancino et al., 2008; Ratnayake et al., 2009) or to apply new processing technology (Gehlhar and Regmi, 2005; Louie et al., 2012; Menard et al., 2011; Savio et al., 2013), all of which may affect the chemical composition of the food products. Food reformulation is defined as "changing the nutrient content of a processed food product to either reduce the content of negative nutrients such as sodium, saturated fat, trans fat or energy (kilojoules) or to increase the content of beneficial nutrients such as dietary fiber, whole-grains, fruit, vegetables and unsaturated fats" (NHFA, 2012). According to the World Health Organization (WHO, 2004), the focus of product reformulation should be on reducing the amount of added sugars, lipids, saturated fatty acids, trans fatty acids and sodium. Simultaneously, it is important to preserve food characteristics such as aroma, flavor, texture and shelf-life, and food components such as dietary fiber (DF), minerals and vitamins (Van Raaij et al., 2009).

Several studies have evaluated nutrient changes in food products, especially in nutrients such as trans fatty acids (Roe et al., 2013) and sodium (Grimes et al., 2011) that are related to the increase in the incidence of non-communicable diseases (NCDs). However, little is known about changes in the formulation of foods concerning more than one main nutrient or groups of specific products.

The methodologies used to evaluate or monitor food reformulation is usually those of percentage change and absolute change, each of which has limitations. Percentage change has an arbitrary nature and may over-represent small changes (Savio et al., 2013). The methods used to obtain absolute change vary greatly; some studies subcategorize food products according to the type of food and then compare the statistical difference between these values

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(Louie et al., 2012; Julia et al., 2015) or classify each product value using traffic lights or by a nutrient profile score established by their country (Savio et al., 2013; Julia et al., 2015 Julia et al., 2015). Due to the great heterogeneity within food groups, hierarchical cluster analysis can be used to cluster foods according to their differences and similarities, in order to further investigate absolute change in chemical composition. The aim of this study was conduct a comparative evaluation of the nutritional profile of specific Brazilian food groups from 2003 and 2013 using various methods of analysis, such as percentage change, hierarchical cluster analysis (HCA), principal component analysis (PCA) and paired Student's *t*-test or Wilcoxon test.

2. Material and methods

2.1. Data collection

Data from the Brazilian Food Composition Database (BFCD) of 2003 (USP, 1998) and from the food groups pre-established according to the Latin America Network on Food Composition (LATINFOODS) (De Pablo and Morón, 2002) were used in order to evaluate changes in many of the food products available on the market. Products belonging to the groups of cereals and cereal products, meat and meat products, milk and milk products, and manufactured foods were identified, and their commercial availability in 2013 was determined both by retailers and on websites.

Analytical reports and updated data were obtained from food manufacturers. Analytical methods accepted for proximate composition data and conversion factors adopted by the BFCD were performed as follows: moisture content was obtained based on weight loss after the sample was heated in a vacuum oven at 70 °C or in an oven at 105 °C (AOAC 920.151); protein by total nitrogen was obtained by the micro-Kjeldahl method (AOAC 960.52) or by a similar analysis considering nitrogen conversion factors recommended by the FAO (1973); lipids were obtained by Soxhlet (AOAC 920.39) or acid hydrolysis (AOAC 922.06); and ash was obtained by incineration in a muffle furnace at 550 °C (AOAC 923.03) (Horwitz and Latimer, 2006). Total DF was obtained by enzymatic-gravimetric (AOAC 991.43) or nonenzymatic-gravimetric methods (for foods with low starch contents) of AOAC (Li and Cardozo, 1992). Available carbohydrates were calculated by the difference between the above-mentioned components (expressed in g/100 g) according to the following equation (Eq. (1)). Results were expressed in g/100 g of wet weight.

$$[100 - (moisture + ash + proteins + lipids + DF)] \quad (1)$$

The energy conversion factors used were: proteins 17 kJ/g; lipids 37 kJ/g; available carbohydrates 17 kJ/g; DF 8 kJ/g and alcohol 29 kJ/g (FAO, 2003). Several food products could not be updated in the BFCD (n = 213) due to the unavailability of analytical reports. Data on carbohydrates, proteins, lipids and the DF content of foods that could not be updated in the BFCD were collected from product labels.

2.2. Evaluation of the nutritional profile of products

Changes in the nutritional profiles of foods were analyzed by percentage change and by multivariate statistical techniques (HCA and PCA) with paired Student's *t*-test or Wilcoxon test.

2.2.1. Percentage change

Changes in the chemical composition of individual food products were assessed by the percentage change in component data from 2013 in relation to 2003 data using Eq. (2):

$$\left[\frac{(2013value - 2003value)}{2013value}\right] x100 \quad (2)$$

Results were classified according to the criteria described by Savio et al. (2013): negligible change (NC – any variation between 0 and 9.99%), moderate reformulation (MR – any variation between 10% and 24.99%) and substantial reformulation (SR – any variation ≥25%). MR and SR can represent an increase or a decrease of the component in comparison to the findings from 2003.

2.2.2. Multivariate statistical analysis

In both the HCA and PCA, food products were assigned to rows and their components (g/100 g of carbohydrates, proteins, lipids and DF) were assigned to columns. The main objective of the HCA was to divide the dataset into clusters in such a manner that there homogeneity in a dataset and heterogeneity between the different clusters (Sneath and Sokal, 1973). A dendrogram was built to identify different clusters based on the hierarchical method, Euclidean distance and complete linkage clustering method (furthest neighbor clustering method). PCA is a technique that reduces data dimensionality and transforms the original measured variables into new uncorrelated variables (principal components) (Berrueta et al., 2007). The PCA was used to examine whether food products could be classified based on their composition (carbohydrates, proteins, lipids and DF).

2.2.3. Univariate statistical analysis

Cluster separations were used to compare the results for food product components obtained in 2003 and 2013. Variables were analyzed for normality of distribution using the Shapiro-Wilk test. Subsequently, a paired Student's *t*-test or Wilcoxon tests were applied. Data were expressed as mean ± standard deviation. Significance levels were set for p-values <0.05. Statistical analyses were performed using IBM® SPSS® Statistics 20.0 software (IBM Inc., New York, NY, USA) and XLSTAT® 2013.03.30882 (Addinsoft SARL, Paris, France). Figures were made using GraphPad® Prism 6.0 software (GraphPad Software, San Diego, CA).

3. Results and discussion

An evaluation of the nutritional profile change of 259 food products from 24 brands was performed in 2013 in comparison to data from 2003. From the total number of products, 71 were categorized into the cereals, 47 into meat, 30 into milk, and 111 were manufactured foods (Supplementary file A). Further analyses were performed to calculate percentage change; HCA, PCA and the clusters formed in HCA were compared using the univariate analysis as described below.

3.1. Percentage change

Percentage change was applied in each food group to verify general differences in composition between 2003 and 2013 (Fig. 1). In the cereals group 77% of products showed NC in energy density; however, 55% (n = 39) and 33% (n = 24) of products showed an MR or SR increase in DF and lipids content, respectively. Interestingly, 40% (n = 19) of products from the meat group showed an increase in lipid content, whereas 53% (n = 16) and 52% (n = 58) of products from the milk and manufactured food groups, respectively, revealed a decrease in lipid content.

Negative changes, such as an increase in energy density and total fat, or a decrease in DF, can make products less healthy. As both positive and negative changes (e.g. an increase in both DF and lipids) can occur simultaneously in the same product, the