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Short communication

Impact of dietary fiber energy on the calculation of food total energy value in the Brazilian Food Composition Database

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ABSTRACT

Dietary fiber (DF) contributes to the energy value of foods and including it in the calculation of total food energy has been recommended for food composition databases. The present study aimed to investigate the impact of including energy provided by the DF fermentation in the calculation of food energy. Total energy values of 1753 foods from the Brazilian Food Composition Database were calculated with or without the inclusion of DF energy. The energy values were compared, through the use of percentage difference (D%), in individual foods and in daily menus. Appreciable energy D% ($\geqslant$10) was observed in 321 foods, mainly in the group of vegetables, legumes and fruits. However, in the Brazilian typical menus containing foods from all groups, only D% <3 was observed. In mixed diets, the DF energy may cause slight variations in total energy; on the other hand, there is appreciable energy D% for certain foods, when individually considered.

1. Introduction

National food composition databases must contain information about energy value and chemical composition of foods that are produced and/or consumed in a certain country. Food energy is determined as the sum of energy values of each macronutrient, which is calculated through the use of conversion factors for nutrients that potentially provide energy to the human body (mainly carbohydrates, proteins, lipids and alcohol) (Charrondière, Chevassus-Agnes, Marroni, & Burlingame, 2004). Energy values are generally expressed as metabolizable energy, defined as the food energy that is available for energy expenditure (heat production) and weight gain. This concept is used in most food composition databases and in food labeling, and it is compatible with the definition of intake recommendation (Warwick, 2005).

However, the Food and Agriculture Organization of the United Nations (FAO) recommends that the energy provided by dietary fiber (DF) fermentation, which is equal to approximately 8 kJ/g, should also be included in the calculation of total energy value (FAO, 2003). The value of 8 kJ/g is based on the fact that around 70% of DF is fermented in the colon and that a part of the energy resulting from this process is lost in the form of gas and in the feces (bacterial biomass) (FAO, 2003; Elia & Cummings, 2007). Most part of the short-chain fatty acids produced during the fermentation process is absorbed in the colon and metabolized by human tissues (Elia & Cummings, 2007).

Since 2008, the European Union established that DF must be included in the calculation of food total energy value for nutritional labeling (European Commission, 2008), which caused changes in some food composition databases. In Brazil, the legislation about mandatory nutritional labeling does not demand this inclusion (Brazil, 2003a). The Brazilian resolution follows the same definitions adopted by the country members of the Southern Common Market Agreement (MERCOSUL) and the nutritional labeling can be provided by food composition databases.

The Brazilian Food Composition Database (BFCD) was created in 1998 and it has been continuously updated (Menezes, Giuntini,

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Dan, & Lajolo, 2009). This database is currently being reformulated under the coordination of Brazilian Network of Food Data Systems (BRASILFOODS), together with the Food and Nutrition Research Center (NAPAN) and Food Research Center (FoRC/CEPID/FAPESP).

In order to comply with the guidelines adopted by other countries and aiming to harmonize databases in relation to energy values, it is necessary to include the DF energy in the calculation of food total energy values in the BFCD. Regarding food carbohydrates, the BFCD considers only the available ones in the calculation of energy; therefore, the inclusion of energy provided by DF may cause an increase in the calculated energy value of foods (Westenbrink, Brunt, & Kamp, 2013). The present work aims to evaluate the impact of including the energy provided by DF fermentation in the calculation of food total energy value in Brazil.

2. Methodology

The following analytical methods accepted for proximate composition data and conversion factors were adopted by the BFCD: moisture content based on weight loss after the sample was heated in a vacuum oven at 70 °C or in an oven at 105 °C; protein by total nitrogen, obtained by micro-Kjeldahl or similar (considering nitrogen conversion factors of FAO, 1973); lipids by Soxhlet or acid hydrolysis; ash by incineration in muffle furnace at 550 °C (Horwitz & Latimer, 2006). Total dietary fiber by enzymatic–gravimetric (Lee, Prosky, & Vries, 1992) or nonenzymatic–gravimetric method (for foods with low starch content) of AOAC (Li & Cardozo, 1992). Available carbohydrates were calculated by difference [100 − (moisture + ash + protein + fat + dietary fiber)]. Data were expressed as g/100 g in wet weight. Only data with the sum of the proximate composition (moisture, ash, available carbohydrate, protein, lipid and dietary fiber) falling within the range 97–103% of analytical sample weight was considered acceptable (Greenfield & Southgate, 2003) and included in the database. Energy conversion factors: protein 17 kJ/g; fat 37 kJ/g; available carbohydrates 17 kJ/g; dietary fiber 8 kJ/g and alcohol 29 kJ/g (FAO, 2003).

2.1. Percentage difference (D%)

The previous energy values (without considering energy provided by DF) were compared to the new ones (considering energy from DF fermentation) according to the following equation:

$$D\% = [(\text{new energy value} - \text{previous energy value})/\text{previous energy value}] \times 100.$$

The D% was considered appreciable when ⩾10% (Padovani, Lima, Colugnati, & Rodriguez-Amaya, 2007; Summer et al., 2013).

In order to evaluate the impact of different calculations of total energy value, the D% was calculated in the BFCD foods individually and in three theoretical complete menus.

2.2. Theoretical daily menus

An estimate of energy intake was done based on theoretical daily menus, that are typically consumed in three different regions of Brazil. The menus were based on data from a Brazilian household budget survey carried out between 2008 and 2009 (IBGE (Brazilian Institute of Geography, 2011) and on the Dietary Guidelines for the Brazilian Population (Brazil, 2014).

Three typical menus were created, each one simulating 4 daily meals of the urban Brazilian population (breakfast, lunch, in-between meal and dinner). The theoretical menus contained foods that are routinely consumed by the Brazilian population, considering the portions recommended by the Brazilian legislation of nutritional labeling in a diet of 8420 kJ (Brazil, 2003b).

- *Southeast Region:* Breakfast – milk, coffee, sugar, bread, butter, cheese; lunch – rice, *feijoada* (made of black beans, sausage and pork meat), *farofa* (made with manioc flour), kale and orange; in-between meal – cheese bread and coffee; dinner – noodles with tomato sauce, roasted chicken, lettuce, papaya.
- *Midwest Region:* Breakfast – milk, coffee, sugar, coconut cake, cheese, papaya; lunch – rice, beans, beef, salad with leaves and tomato, pineapple; in-between meal – milk, coffee, sugar, corn cake; dinner – rice, beans, minced meat with carrots and green beans.
- *Northeast Region:* Breakfast – milk, sugar, *tapioca* (similar to a crepe, made with manioc starch and water), banana; lunch – rice, beans, fish with sauce, lettuce, *cocada* (dessert made with coconut and sugar); in-between meal – milk, coffee, sugar, *cuscuz* (made with corn flour); dinner – rice, beans, grilled chicken breast, squash, *goiabada* (dessert made with guava and sugar).

2.3. Statistical analysis

Pearson's correlation coefficient was calculated using the software Statistica 11.0 (StatSoft Inc., Tulsa, OK, USA) in order to verify the relation between DF content and energy D% of foods from the BFCD after the inclusion of energy provided by DF fermentation.

3. Results and discussion

The BFCD currently contains information on proximate composition of 1753 foods. In 321 foods appreciable percentage difference (D% ⩾ 10) was found between previous (without considering energy from DF) and new (considering energy from DF fermentation) energy values. As expected, a large number of foods belonging to DF-source groups presented appreciable energy D%, which was observed in 152 out of 228 foods belonging to the group of vegetables, in 55 out of 83 foods from the group of legumes, followed by 79 out of 238 foods from the group of fruits. However in the case of the group of cereals, an appreciable D% was observed only in 12 out of 247 foods. Among the foods that presented the highest D% after including DF energy, it is possible to mention: jambo (*Eugenia malaccencis* L.) (D% = 97) and cooked jalo beans (*Phaseolus vulgaris* L.) (D% = 66). On the other hand, it is possible to observe little D% in foods such as raw green pepper (*Capsicum annuum* L.) (D% = 6), raw yellow manioc (*Manihot esculenta* Crantz) (D% = 3), *in natura* palmer mango (*Mangifera indica* L.) (D% = 4) and *in natura* watermelon (*Citrullus lanatus* Thunb) (D% = 1).

Table 1 shows the energy D% found in some foods that are consumed by the Brazilian population. It is possible to observe great variation in foods belonging to the same group. In the group of cereals, cereal bars correspond to the majority of foods that present appreciable D%. In this case, energy D% varied from 2% to 14% due to differences in the DF content and hence in the available carbohydrate contents, which is calculated by difference. The same was observed in two different breakfast cereals: one presented 49.2 g of available carbohydrates and 35 g of DF, while the second one presented 73.9 g of available carbohydrates and 9.3 g of DF, with energy D% of 26% and 5%, respectively (Table 1). Therefore, the DF content can affect the energy value in foods that contain large quantities of this component. It is important to highlight that, in the case of some refined and whole-grain products, although they present great variation in DF content, the D% was similar. This was verified in polished rice (D% = 2) and whole-grain rice

Table 1

Proximate composition and energy (100 g, wet weight) and energy D% of two different energy calculations (excluding and including energy provided by dietary fiber) of some foods from the Brazilian Food Composition Database usually consumed by the population.

	D%[a]	New energy value (kJ) (including DF)[b]	Previous energy value (kJ) (excluding DF)[c]	Moisture (g)	Protein (g)	Fat (g)	Available carbohydrates[d] (g)	Ash (g)	Dietary fiber[e] (g)
Group of cereals									
Cereal, bar, orange, Nestlé®	**14**	1476	1300	8.3	5.5	6.5	56.8	0.90	22.0
Cereal, bar, nuts/raisins/honey, Ritter	2	1629	1592	7.8	6.8	6.4	73.0	1.42	4.6
Rice, polished, cooked, *Oryza sativa* L.	2	450	442	73.5	2.1	0.6	22.6	0.30	1.0
Rice, whole grain, cooked, *Oryza sativa* L.	3	415	403	75.5	2.3	0.7	19.8	0.22	1.5
Cereal, wheat and corn, “Fibra Mais”	**26**	1351	1071	3.1	7.3	3.0	49.2	2.41	35.0
Cereal, wheat/rice/corn, Nesfit®	5	1551	1476	2.6	9.3	1.7	73.9	3.19	9.3
Cracker, salted, whole grain, Nestlé®	2	1944	1904	2.6	12.3	18.3	59.8	1.95	5.0
Cracker, salted	1	1892	1876	4.1	8.1	15.6	68.3	1.90	2.0
Group of vegetables									
Tomato, raw, *Lycopersicum esculentum* M.	**17**	74	63	94.9	1.2	0.3	1.8	0.45	1.4
Pumpkin, cooked, *Cucurbita máxima* x *Cucurbita moschata*	**10**	212	193	86.4	1.4	0.7	8.3	0.71	2.5
Chayote, cooked, *Sechium edule*	**17**	96	82	93.6	0.6	0.3	3.6	0.19	1.7
Cucumber, raw, *Cucumis sativus* L.	**33**	35	27	97.1	0.5	0.1	0.9	0.31	1.1
Lettuce, raw, *Lactuca sativa* L.	**28**	46	36	96.3	0.9	0.1	0.9	0.51	1.3
Kale, raw, *Brassica oleracea* var. acephala	**28**	115	90	90.9	2.9	0.5	1.2	1.35	3.1
Cabbage, white, raw, *Brassica oleracea* L.	**21**	74	61	94.5	1.0	0.1	2.3	0.43	1.6
Sweet potato, cooked, *Ipomoea batatas* Lam	5	514	488	67.7	1.2	0.3	26.8	0.68	3.3
Potato, white, cooked, *Solanum tuberosum* L.	6	229	216	85.4	1.5	0.1	11.0	0.40	1.6
Cassava, cooked, *Manihot esculenta* C.	3	502	486	69.1	0.7	0.2	27.5	0.52	2.0
Group of fruits									
Orange, in natura, *Citrus aurantium* L.	**12**	146	131	90.2	0.7	0.3	6.4	0.47	2.0
Banana, in natura, *Musa* ssp.	3	356	344	78.0	1.3	0.3	18.3	0.71	1.5
Apple, fuji, with skin, in natura, *Malus sylvestris* Mill	7	274	256	83.3	0.2	0.7	13.3	0.23	2.3
Papaya, in natura, *Carica papaya* L.	**12**	169	150	88.8	0.6	0.3	7.7	0.35	2.3
Mango, in natura, *Mangifera indica* L.	**10**	281	255	82.1	0.4	0.6	13.2	0.34	3.3
Tangerine, in natura, *Citrus reticulata*	5	171	163	89.2	0.8	0.1	8.6	0.31	0.9
Group of legumes									
Beans, black, cooked, *Phaseolus vulgaris* L.	**15**	574	497	67.5	7.3	0.8	20.3	1.07	9.6
Beans, carioca, cooked, *Phaseolus vulgaris* L.	**15**	338	293	77.2	4.8	0.5	11.3	0.59	5.6

[a] D% (percentage difference) = [(new energy value − previous energy value)/previous energy value] × 100.
[b] Energy conversion factors: protein 17 kJ/g; fat 37 kJ/g; available carbohydrates 17 kJ/g; dietary fiber 8 kJ/g.
[c] Energy conversion factors: protein 17 kJ/g; fat 37 kJ/g; available carbohydrates 17 kJ/g.
[d] Available carbohydrates were calculated by difference [100 − (moisture + ash + protein + fat + dietary fiber)].
[e] Total dietary fiber determined by enzymatic–gravimetric method of AOAC. Values in bold present appreciable energy percentage difference (D% ⩾ 10) between two different energy calculations.

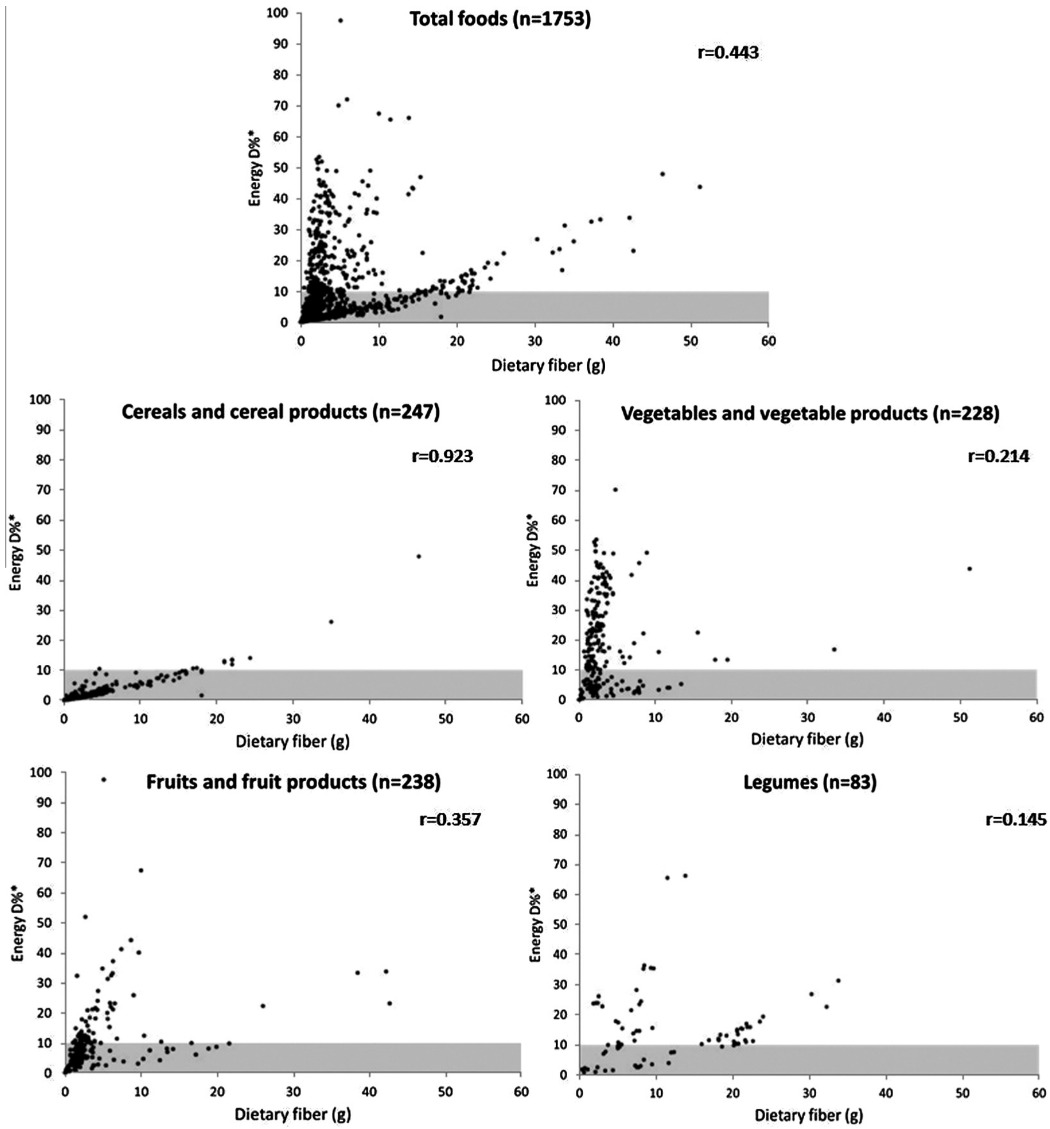

Fig. 1. Relation between dietary fiber content (g/100 g, wet weight) and energy D% of two different energy calculations of foods from the Brazilian Food Composition Database.

Table 2
Nutrients, energy and energy D% of two different energy calculations (excluding and including energy provided by dietary fiber) in theoretical daily menus that are typical in three Brazilian regions (SE – Southeast; MW – Midwest; NE – Northeast).

	D%[a]	New energy value (kJ) (including DF)[b]	Previous energy value (kJ) (excluding DF)[c]	Protein (g)	Fat (g)	Total carbohydrates[d] (g)	Available carbohydrates[e] (g)	Dietary fiber[f] (g)
SE	2.9	8679	8433	94.3	81.2	255.8	225.0	30.8
MW	2.4	8677	8474	86.8	80.8	261.1	235.8	25.3
NE	2.7	8662	8438	76.2	58.4	321.0	292.9	28.1

[a] D% (percentage difference) = [(new energy value − previous energy value)/previous energy value] × 100.
[b] Energy conversion factors: protein 17 kJ/g; fat 37 kJ/g; available carbohydrates 17 kJ/g; dietary fiber 8 kJ/g.
[c] Energy conversion factors: protein 17 kJ/g; fat 37 kJ/g; available carbohydrates 17 kJ/g.
[d] Total carbohydrates were calculated by difference [100 − (moisture + ash + protein + fat)].
[e] Available carbohydrates were calculated by difference [100 − (moisture + ash + protein + fat + dietary fiber)].
[f] Total dietary fiber determined by enzymatic–gravimetric method of AOAC.

(D% = 3); as well as in salted cracker (D% = 1) and whole-grain salted cracker (D% = 2).

Although the DF content may relevantly affect some food energy values, a correlation between energy D% and DF content was only possible to be made in the group of cereals ($r = 0.923$) (Fig. 1). At the same time, foods belonging to the same group, presenting similar DF contents, may present varying D%. One good example is the observation made in the group of vegetables: boiled sweet potato (*Ipomoea batatas* L. Lam.) and raw kale (*Brassica oleracea* var. Acephala), with similar DF content (3.3 and 3.1 g/100 g), presented D% of 5% and 28%, respectively. When comparing the proximate composition of these two foods, the content of available

Table 3
Examples of conversion factors used to calculate energy value in different food composition tables/databases.

Food composition table/ database	Protein	Fat	Carbohydrates	Dietary fiber	Polyols	Organic acids	Alcohol	Comments
Danish Food Composition Databank version 7.01 (Denmark)	17 kJ	37 kJ	17 kJ	8 kJ	–	–	29 kJ	Carbohydrate: available, calculated by difference Available in: http://www.foodcomp.dk
Dutch Food Composition Database version 2013/ 4.0 (NEVO) (Netherlands)	17 kJ	37 kJ	17 kJ	8 kJ	10 kJ	13 kJ	29 kJ	Carbohydrate: sum of mono-, di- and polysaccharides, when possible; or calculated by difference Available in: http://www.rivm.nl/en/Topics/D/Dutch_Food_Composition_Database
New Zealand Food Composition Database version 2013 (New Zealand)	16.7 kJ	37 kJ	16.7 kJ	8 kJ	–	–	29.3 kJ	Carbohydrate: available Two types of energy data (energy, total metabolizable and energy, total metabolizable including fiber) Available in: http://www.foodcomposition.co.nz
Czech Food Composition Database version 4.13 (Czech Republic)	17 kJ	37 kJ	17 kJ	8 kJ	–	13 kJ	29 kJ	Carbohydrate: available, calculated by difference Available in: http://www.nutridatabaze.cz/en/
French food composition table Ciqual version 2013 (France)	17 kJ	37 kJ	17 kJ	8 kJ	10 kJ	13 kJ	29 kJ	Carbohydrate: any carbohydrate which is metabolized in man Available in: https://pro.anses.fr/TableCIQUAL/
Souci–Fachmann–Kraut Online Database 7th edition (Germany)	17 kJ	37 kJ	17 kJ	–	–	13 kJ	29 kJ	Carbohydrate: available. For the majority of the food products this value was determined as the total of the individual data for mono-, oligo- and polysaccharides and sugar alcohols Available in: http://www.sfk-online.net/cgi-bin/sfkstart.mysql?
Canadian Nutrient File version 2010 (Canada)	SAF	SAF	SAF	–	–	–	–	Carbohydrate: total, calculated by difference Available in: http://www.hc-sc.gc.ca/fn-an/nutrition/fiche-nutri-data/index-eng.php
USDA National Nutrient Database for Standard Reference release 27 (United States)	SAF	SAF	SAF	–	–	–	–	Carbohydrate: total, calculated by difference Available in: http://ndb.nal.usda.gov/ndb/
Food Composition Table version 2010 (Argentina)	4 kcal	9 kcal	4 kcal	–	–	–	–	Carbohydrate: total, calculated by difference Available in: http://www.unlu.edu.ar/~argenfoods/Tablas/Tabla.htm
Chilean Food Composition Table 8th edition (Chile)	SAF or 4 kcal	SAF or 9 kcal	SAF or 4 kcal	*	–	–	–	Carbohydrate: available, calculated by difference Available in: http://mazinger.sisib.uchile.cl/repositorio/lb/ciencias_quimicas_y_farmaceuticas/schmidth03
Peruvian Food Composition Tables version 2009 (Peru)	SAF	SAF	SAF	–	–	–	–	Carbohydrate: available, calculated by difference when dietary fiber values are available; or total by difference Available in: http://www.ins.gob.pe/insvirtual/images/otrpubs/pdf/Tabla%20de%20Alimentos.pdf
Brazilian Food Composition Database version 5.0 (Brazil)	17 kJ	37 kJ	17 kJ	8 kJ	–	–	29 kJ	Carbohydrate: available, calculated by difference Not available on line (data in reformulation phase)

Note: SAF, Specific Atwater Factors.
* Crude fiber or cellulose

carbohydrates is much higher in the sweet potato, while kale presents higher moisture content (Table 1). Therefore, the impact of DF energy depends on each food matrix, which prevents any kind of generalization to be made.

In Brazil, the most frequently consumed foods are beans and polished rice (IBGE, 2011), which presented energy D% of 15% and 2%, respectively. Due to the great variability found in routinely-consumed foods, it is also important to evaluate the magnitude of this variability in mixed diets.

The proposed menus in the present work were based in eating habits from different Brazilian regions and contain several foods (presented in Table 1) with wide energy D%. However, when the energy value was calculated in the three different 24-h menus of around 8400 kJ each (Table 2), the energy provided by DF fermentation resulted in an increase of 203–246 kJ, which represented a maximum of D% = 3. According to the distribution of macronutrients in the menus (presented in Table 2), there was also an important variation in lipid contents, and hence in carbohydrates calculated by difference; however, this fact did not interfere in the energy D%.

Despite several large differences found in individual foods, it tends to be less relevant in the evaluation of mixed diets. A 24-h diet also contains foods without dietary fiber (such as oil, sugar and meat) which, in the present study, contributed with approximately 50% of the total energy, diluting the effect of energy provided by DF.

A recent study analyzed 3-day food records of Australian adults using the US-based Nutrition Data System for Research, modified to reflect food items consumed in Australia, and the Australian Food and Nutrient Database. Median intakes of energy, carbohydrate, protein and DF differed by <5% at the group level, among both databases. However, the authors affirm that, when comparing individual intakes, more than 10% difference was observed regarding energy and lipid, in a significant part of participants (35% and 69%, respectively) (Summer et al., 2013). Therefore, the differences individually observed will not necessarily reflect the ones found at

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the group level, not only in the case of population groups, but also in foods, which is the case of the present study that evidenced an impact on energy for some foods, but not for a mixed diet.

Comparing energy values provided by databases of different countries is usually impracticable, because different conversion factors and nutrient definitions are adopted (Table 3) and may interfere in energy calculation (Charrondière et al., 2004). Moreover, the inclusion of compounds such as polyols, organic acids and alcohol can be considered in this calculation. Not many databases provide information on these components in an isolated way, since they are either found in only a few foods or not analyzed (Greenfield & Southgate, 2003). In the case of databases that do not consider those compounds, the calculation of carbohydrates by difference include polyols and organic acids in total carbohydrate values (Charrondière et al., 2004). The BFCD (data in reformulation phase) adopts Atwater factors for protein, lipids, available carbohydrates by difference and alcohol, and the FAO factor for DF (FAO, 2003). These same factors are only used by Denmark, Czech Republic and Germany, additionally include organic acids, while the French and the Dutch databases also include polyols (Table 3). Moreover, it is important to observe that the consequence of including 8 kJ/g (provided by DF) depends on how food energy was previously calculated. In databases that consider total carbohydrates in energy calculation, the separation of carbohydrates into "available" and "DF" will result in a decrease in energy value, since 17 kJ was attributed to DF instead of 8 kJ/g.

As seen in Table 3, several types of energy calculation are adopted in different countries, which was discussed in a study involving Finland, Germany, Sweden and the USA. The authors evaluated the association between diabetes and environmental factors, such as diet, and they concluded that it is necessary to recalculate energy using the same factors, in order to have comparable data (Uusitalo et al., 2011). All these variations reinforce, once again, the importance of harmonizing definitions, calculations and analytical methodology among food composition databases. In the case of energy value calculation, adopting the DF factor, as recommended by FAO, would avoid an over or underestimation of food energy.

4. Conclusions

The inclusion of energy provided by the dietary fiber (DF) fermentation in the calculation of total energy values of 1753 Brazilian foods resulted in appreciable energy percentage differences ($10 \leqslant D\% \leqslant 97$) for 321 foods. In the groups of vegetables and legumes, this difference was observed in more than half of the foods. When the same calculation was applied in typical Brazilian menus, the energy D% was approximately equal to 3%. These results emphasize that including energy provided by DF does not have impact on total energy value of mixed diets, which, on the other hand, is observed when foods are individually considered.

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