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A new method for calculating copper content and determining appropriate copper levels in foods

Un nuevo método para calcular el contenido de cobre y determinar los niveles apropiados de cobre en los alimentos

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ABSTRACT

Since the amount of food can affect the copper content, the copper content of different amounts of food (except foods without copper) is different. The copper content of some foods is inappropriately calculated per 100 kcal, 100 g or 100 mL, or the reference amount customarily consumed (RACC). Thus, making some food choices based on these calculations to achieve adequate copper intake may increase the risk of some chronic diseases. Calculating the copper content and determining appropriate copper levels (to achieve adequate copper intake) based on U.S. Food and Drug Administration (FDA), Codex Alimentarius Commission (CAC), and the proposed method were performed in 7,379 food items. Making some food choices based on the FDA and CAC per serving (the serving is derived from the RACC) or CAC per 100 g or 100 mL to achieve adequate copper intake exceeded energy needs, which could lead to overweight or obesity. Making some food choices based on the CAC per 100 kcal or CAC per 100 g or 100 mL to achieve adequate copper intake did not meet copper requirements, which could lead to copper deficiency. Some foods that met copper requirements were not appropriate food choices based on the CAC per 100 g or 100 mL or CAC per serving to achieve adequate copper intake. On the basis of the proposed method, calculating the copper content and determining appropriate copper levels in foods are performed by considering RACCs and the energy content of foods. Thus, making food choices based on the proposed method met copper requirements and did not exceed energy needs.

Abbreviations: CAC, Codex Alimentarius Commission; FDA, U.S. Food and Drug Administration; FAO, Food and Agriculture Organization; WHO, World Health Organization; RACC, reference amount customarily consumed; DV, daily value; NRV, nutrient reference value; DRV, daily reference value.

Keywords: Adequate copper; Copper deficiency; Copper-poor foods; Copper-rich foods; Dietary copper; Obesity.

RESUMEN

Dado que la cantidad de alimento puede afectar el contenido de cobre, el contenido de cobre de diferentes cantidades de alimentos (excepto los alimentos sin cobre) puede ser diferente. El contenido de cobre de algunos alimentos se calcula incorrectamente por 100 kcal, 100 g o 100 mL, o la cantidad de referencia habitualmente consumida (RACC). Por lo tanto, elegir algunos alimentos en función de ellos para lograr una ingesta adecuada de cobre puede aumentar los riesgos de algunas enfermedades crónicas. El cálculo del contenido de cobre y la determinación de los niveles apropiados de cobre (para lograr una ingesta adecuada de cobre) en 7.379 alimentos según métodos de la Administración de Drogas y Alimentos de los Estados Unidos (FDA), la Comisión del Codex Alimentarius (CAC) y por el método propuesto en este trabajo. La elección de alimentos basadas en la FDA y el CAC por porción (la porción se deriva del RACC) o CAC por 100 g o 100 ml, para lograr una ingesta adecuada de cobre, excedió las necesidades energéticas, lo que podría provocar sobrepeso u obesidad. La elección de alimentos basadas en el CAC por 100 kcal o CAC por 100 g o 100 ml para lograr una ingesta adecuada de cobre no cumplió con los requisitos de cobre, lo que podría conducir a una deficiencia de cobre. Algunos alimentos que cumplían con los requisitos de cobre no eran opciones de alimentos adecuadas según el CAC por 100 g o 100 ml o el CAC por porción, para lograr una ingesta adecuada de cobre. Sobre la base del método propuesto, el cálculo del contenido de cobre y la determinación de los niveles apropiados de cobre en los alimentos se realizaron considerando las RACC y el contenido energético de los alimentos. Por lo tanto, la elección de alimentos basada en el método propuesto cumplió con los requisitos de cobre y no excedió las necesidades energéticas.

Palabras clave: Adecuación de cobre; Alimentos ricos en cobre; Cobre dietario; Deficiencia de cobre; Obesidad.

INTRODUCTION

Copper functions as a component in a number of metalloenzymes acting as oxidases to achieve the reduction of molecular oxygen^{1,2}. Copper is involved in cellular respiration, antioxidant defense, connective tissue formation, neurotransmitter biosynthesis, peptide hormone maturation, pigmentation, keratinization, and iron homeostasis³. Since the amount of food can affect the copper content, the copper content of different amounts of food (except foods without copper) is different. The copper content of some foods is inappropriately calculated per 100 kcal, 100 g (for solids) or 100 mL (for liquids), or RACC. Thus, making some food choices based on these calculations to achieve adequate copper intake may increase the risk of some chronic diseases. According to the regulatory requirements for nutrient content claims, appropriate copper levels (to achieve adequate copper intake) in foods should be determined based on the source and high claims for copper. The source and high claims for copper indicate the presence of copper at mid and high levels, respectively. If one food meets the definition of high or source claim for copper, that food is considered high copper (excellent source of copper) or copper source (good source of copper), respectively. Foods that meet the source or high claim for copper are known as foods containing appropriate copper levels. Nutrient content claims were established by several authorities, and the CAC and FDA are the most important among them. The CAC is an intergovernmental body with 189 members (188 member countries and 1 member organization, including the European Union), within the framework of the Joint FAO/WHO Food Standards Program established by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), with the purpose of protecting the health of consumers and ensuring fair practices in food trade⁴. The source and high claims for copper based on the CAC are expressed in reference amounts of 100 g or 100 mL, serving size (serving), and 100 kcal, and the source and high claims for copper based on the FDA are expressed

in a reference amount of serving. According to the source and high claims for copper under the FDA and CAC per serving, the serving is derived from the RACC.

This study examined calculating the copper content and determining appropriate copper levels based on the FDA and CAC per serving, CAC per 100 g or 100 mL, and CAC per 100 kcal and introduced a new method for calculating the copper content and determining appropriate copper levels in foods. On the basis of the proposed method, calculating the copper content and determining appropriate copper levels in foods are performed by considering RACCs and the energy content of foods. The proposed method was used for calculating contents and determining appropriate levels of calcium⁵ first and then thiamin⁶ in foods.

METHODS

Food items

Information on food and copper profiles was provided from the USDA National Nutrient Database for Standard Reference, release 28 (SR28)⁷. Of 8,790 food items in the SR28, information on the copper content of 1,257 food items was missing.

Food groups

Food groups were not provided in the SR28 Excel data file. However, the preparation of results on the basis of food groups required the allocation of food groups to food items. Thus, food groups were allocated to SR28 food items using the FoodData Central website (<https://fdc.nal.usda.gov>).

RACCs

RACC values represent the amount (edible portion) of food customarily consumed per eating occasion⁸. RACCs were not provided in the SR28 Excel data file. However, the preparation of results on the basis of the serving required the allocation of RACCs to food items. Thus, RACCs were allocated to SR28 food items using the guidance prepared by the Office

of Nutrition and Food Labeling⁸. RACCs were allocated to 8,596 food items, and 194 food items were excluded due to the lack of density or RACC.

Calculation of copper content per 100 mL

The copper content of food items in the SR28 was provided per 100 g. Since the copper content of liquid food items based on the CAC per 100 mL should have been provided per 100 mL, the densities of liquid food items were calculated using Formula 1. Then, the copper content was converted from 100 g to 100 mL using Formula 2. Solid and liquid foods refer to foods that are usually measured by weight and volume, respectively.

$$\text{Formula 1: Density}_{(g/mL)} = \text{mass}_{(g)} \div \text{volume}_{(mL)}$$

$$\text{Formula 2: Copper content}_{(mg)} \text{ per 100 mL (for liquids)} = \text{density}_{(g/mL)} \times \text{copper content}_{(mg)} \text{ per 100 g}$$

Calculation of copper content per 100 kcal

Since the copper content of food items based on the CAC per 100 kcal should have been provided per 100 kcal, the copper content of food items was converted from 100 g to 100 kcal using Formula 3.

$$\text{Formula 3: Copper content}_{(mg)} \text{ per 100 kcal} = (100 \div \text{energy}_{(kcal/100 g)}) \times \text{copper content}_{(mg)} \text{ per 100 g}$$

Calculation of copper content per RACC

Since the copper content of food items based on the

FDA and CAC per serving should have been provided per RACC, the copper content was converted from 100 g to RACC using Formula 4 for solids and Formula 5 for liquids.

$$\text{Formula 4: Copper content}_{(mg)} \text{ per RACC (for solids)} = (\text{RACC}_{(g)} \div 100) \times \text{copper content}_{(mg)} \text{ per 100 g}$$

$$\text{Formula 5: Copper content}_{(mg)} \text{ per RACC (for liquids)} = (\text{RACC}_{(mL)} \div 100) \times \text{density}_{(g/mL)} \times \text{copper content}_{(mg)} \text{ per 100 g}$$

Daily values or nutrient reference values for copper

Daily values (DVs) or nutrient reference values (NRVs) for copper were considered 0.9 mg⁹ (21 CFR101.9, revised as of April 1, 2018) for all foods, excluding baby foods, and 0.3 mg (21 CFR101.9, revised as of April 1, 2018) for baby foods in this study.

DVs or daily reference values for energy

DVs or daily reference values (DRVs) for energy were considered 2,000 kcal⁹ (21 CFR101.9, revised as of April 1, 2018) for all foods, excluding baby foods, and 1,000 kcal (21 CFR101.9, revised as of April 1, 2018) for baby foods in this study.

Source and high claims for copper

Table 1 presents the source and high claims for copper based on the proposed method, FDA and CAC per serving, CAC per 100 g or 100 mL, and CAC per 100 kcal.

Calculation of copper content of foods based on

Table 1. Source (good source) and high (excellent source) claims for copper based on the proposed method, FDA and CAC per serving, CAC per 100 g or 100 mL, and CAC per 100 kcal.

Claim	Proposed method	FDA per serving ¹⁰	CAC per 100 g or 100 mL, 100 kcal, and serving ^{4,11}
Source claim for copper	2,000 kcal: 10-19% of DV for copper per RACC (and per 200 kcal of RACC if RACC is more than 200 kcal) 1,000 kcal: 10-19% of DV for copper per RACC (and per 100 kcal of RACC if RACC is more than 100 kcal)	10-19% of DV for copper per RACC	100 g: 15-29% of NRV for copper per 100 g 100 mL: 7.5-14% of NRV for copper per 100 mL 100 kcal: 5-9% of NRV for copper per 100 kcal Serving: 15-29% of NRV for copper per RACC
High claim for copper	2,000 kcal: 20% or more of DV for copper per RACC (and per 200 kcal of RACC if RACC is more than 200 kcal) 1,000 kcal: 20% or more of DV for copper per RACC (and per 100 kcal of RACC if RACC is more than 100 kcal)	20% or more of DV for copper per RACC	100 g: 30% or more of NRV for copper per 100 g 100 mL: 15% or more of NRV for copper per 100 mL 100 kcal: 10% or more of NRV for copper per 100 kcal Serving: 30% or more of NRV for copper per RACC

The proposed method in conditions of appropriate energy content

If the energy content per RACC is 200 kcal or less, the copper content of all foods (based on the reference energy intake of 2,000 kcal), excluding baby foods, is calculated per RACC, and if the energy content per RACC is 100 kcal or less, the copper content of baby foods (based on the reference energy intake of 1,000 kcal) is calculated per RACC. Also, if the energy content per RACC is 200 kcal or less, the source and high claims for copper are defined respectively as 10-19% and 20% or more of the DV for copper per RACC in all foods, excluding baby foods, and if the energy content per RACC is 100 kcal or less, the source and high claims for copper are defined respectively as 10-19% and 20% or more of the DV for copper per RACC in baby foods. The energy content per RACC for solid and liquid foods was calculated using Formulas 6 and 7, respectively.

Formula 6: Energy content_(kcal) per RACC (for solids) = $(\text{RACC}_{(g)} \div 100) \times \text{energy}_{(kcal/100\text{ g})}$

Formula 7: Energy content_(kcal) per RACC (for liquids) = $(\text{RACC}_{(mL)} \div 100) \times (\text{density}_{(g/mL)} \times \text{energy}_{(kcal/100\text{ g})})$

Calculation of copper content of foods (except baby foods) based on the proposed method in conditions of inappropriate energy content

If the energy content per RACC is more than 200 kcal, the copper content of all foods (based on the reference energy intake of 2,000 kcal), excluding baby foods, is calculated per 200 kcal of RACC. Also, if the energy content per RACC is more than 200 kcal, the source and high claims for copper are defined respectively as 10-19% and 20% or more of the DV for copper per 200 kcal of RACC in all foods, excluding baby foods. If the energy content per RACC is more than 200 kcal, 200 kcal of RACC for solid and liquid foods is calculated using Formulas 8 and 9, respectively.

Formula 8: 200 kcal of RACC_(g) (for solids) = $[200 \times \text{RACC}_{(g)}] \div [(\text{RACC}_{(g)} \div 100) \times \text{energy}_{(kcal/100\text{ g})}]$

Formula 9: 200 kcal of RACC_(mL) (for liquids) = $[200 \times \text{RACC}_{(mL)}] \div [(\text{RACC}_{(mL)} \div 100) \times (\text{density}_{(g/mL)} \times \text{energy}_{(kcal/100\text{ g})})]$

Calculation of copper content of baby foods based on the proposed method in conditions of inappropriate energy content

If the energy content per RACC is more than 100 kcal, the copper content of baby foods (based on the reference energy intake of 1,000 kcal) is calculated per 100 kcal of RACC. Also, if the energy content per RACC is more than 100 kcal, the source and high claims for copper are defined respectively as 10-19% and 20% or more of the DV for copper per 100 kcal of RACC in baby foods. If the

energy content per RACC is more than 100 kcal, 100 kcal of RACC for solid and liquid baby foods is calculated using Formulas 10 and 11, respectively.

Formula 10: 100 kcal of RACC_(g) (for solids) = $[100 \times \text{RACC}_{(g)}] \div [(\text{RACC}_{(g)} \div 100) \times \text{energy}_{(kcal/100\text{ g})}]$

Formula 11: 100 kcal of RACC_(mL) (for liquids) = $[100 \times \text{RACC}_{(mL)}] \div [(\text{RACC}_{(mL)} \div 100) \times (\text{density}_{(g/mL)} \times \text{energy}_{(kcal/100\text{ g})})]$

RESULTS

Foods containing appropriate copper levels based on the proposed method

About 97% of foods contained copper. On the basis of the proposed method, the average (%) of foods containing appropriate copper levels in food groups was 41.24%, of which 23.92% was the average of copper source (good source of copper) foods, and 17.32% was the average of high copper (excellent source of copper) foods. Legumes and legume products with 95.3%, nut and seed products with 91.85%, baby foods with 87.64%, lamb, veal, and game products with 69.2%, breakfast cereals with 58.47%, and cereal grains and pasta with 55.8% had the highest averages of foods containing appropriate copper levels (Figure 1).

The highest amounts of copper were found in liver, kidney, heart, beef sweetbread, oyster, squid, oyster stew, whelk, rowal fruit, northern lobster, potato skins, sesame butter, kale, whole sesame seeds, soy-based protein powder, winged bean tuber, mushrooms, vermicelli made from soy, pork rump ham, crab, winged beans, cuttlefish, veal spleen, beef spleen, soy chips or soy crisps, breadnut tree seeds, cashew butter, milk-based protein supplement (copper-fortified), cashew nuts, quail meat, squab or pigeon meat, dove meat, whey protein powder isolate (copper-fortified), vegetarian fillets, turkey giblets, octopus, soy flour, meatless meatballs, meatless chicken, clam, crayfish, soybeans, Steller sea lion meat, peanut butter, sunflower seed kernels, hearts of palm, mixed nuts, cocoa-rich chocolate, chocolate instant breakfast powder (copper-fortified), hazelnuts or filberts, safflower seed kernels, Brazil nuts, sunflower seed butter, chocolate soymilk, spirulina seaweed, nutrition shake (copper-fortified), meatless luncheon slices, papad, buckwheat, Canada goose meat, baking chocolate, hemp seeds, tempeh, English walnut, hyacinth beans, and pink or red lentils. Since cocoa is high in copper, the presence of cocoa in foods such as chocolate and chocolate-containing foods increases the copper content of these foods.

Foods containing appropriate copper levels were found in all food groups, excluding fats and oils and spices and herbs. Foods containing appropriate copper levels included foods of plant and animal origin. However, few numbers of foods containing appropriate copper levels were copper-fortified foods. The absence of foods containing appropriate copper levels in spices and herbs is due to the fact that spices and herbs are customarily consumed in small amounts. Spices and herbs provide sensory attributes such as flavor, aroma, and color to food¹².

Achieving the DVs for copper by consuming high copper foods required consuming an average of 3.2 servings. So, the DVs for copper are easily achieved by consuming high copper foods. Achieving the DVs for copper by consuming copper source foods required consuming an average of 7.6 servings. So, the DVs for copper are moderately achieved by consuming copper source foods. Since achieving the DVs for copper without consuming high copper and copper source foods required consuming more than 10 servings (or more than 20 servings in 26.7% of foods), it is difficult to achieve the DVs for copper without consuming high copper and copper source foods. According to the proposed method, the serving is derived from the RACC or 200 kcal of RACC for all foods, excluding baby foods, and RACC or 100 kcal of RACC for baby foods. The averages (%) of foods containing appropriate copper levels based on the proposed method in food groups are shown in figure 1.

Foods containing appropriate copper levels based on the FDA per serving

Since calculating the copper content and determining appropriate copper levels based on the FDA per serving are performed without considering the energy content of foods, making some food choices based on the FDA per serving to achieve adequate copper intake met copper requirements but exceeded energy needs. For example, if one cheese quesadilla (NDB number 36.052) contains

368 kcal of energy per 100 g, RACC of 140 g, and 0.0966 mg of copper per RACC, is it defined as high copper or copper source food based on the proposed method and FDA per serving? Since this quesadilla contains 0.0966 mg of copper per RACC, it is defined as copper source food based on the FDA per serving. Consuming 9.317 RACCs of the quesadilla meets the DV for copper but results in receiving 4,800 kcal of energy, which is 2,800 kcal more than the DV or DRV for energy. Since the serving of this quesadilla based on the proposed method is 54.35 g, and this amount of quesadilla contains 0.04 mg of copper, this quesadilla is not defined as high copper or copper source food based on the proposed method (Figure 2).

The average (%) of similarities between the proposed method and the FDA per serving was 95.18% for high copper and copper source foods in food groups. Both the proposed method and FDA per serving had the same high copper and copper source foods in nine and eight food groups, respectively. However, calculating the copper content of some foods in large amounts (due to not considering the energy content of foods) based on the FDA per serving increased the averages (%) of foods containing appropriate copper levels in 14 food groups (fast food; restaurant food; meals, entrees, and side dishes; lamb, veal, and game products; pork products; baked products; American Indian/Alaska Native foods; beef products; poultry products; dairy and egg products; baby foods; sweets; beverages; fruits and

Figure 1: Averages (%) of foods containing appropriate copper levels (to achieve adequate copper intake) based on the proposed method in food groups. All high copper (excellent source of copper) and copper source (good source of copper) foods, excluding high copper and copper source baby foods, are based on the reference energy intake of 2,000 kcal for adults and children aged 4 years and older. High copper and copper source baby foods are based on the reference energy intake of 1,000 kcal for children 1 through 3 years of age.

fruit juices) as compared with the proposed method. For example, the averages (%) of foods containing appropriate copper levels in fast foods, restaurant foods, and meals, entrees, and side dishes were respectively 80.49%, 57.61%, and 77.78% based on the FDA per serving and 26.22%, 27.17%, and 52.38% based on the proposed method.

Foods containing appropriate copper levels based on CAC per serving

Since calculating the copper content and determining appropriate copper levels based on CAC per serving are performed without considering the energy content of foods, making some food choices based on the CAC per serving to achieve adequate copper intake met copper requirements but exceeded energy needs. For example, if one fish sandwich (NDB number 21258) contains 260 kcal of energy per 100 g, RACC of 195 g, and 0.1463 mg of copper per RACC, is it defined as high copper or copper source food based on the proposed method and CAC per serving? Since this sandwich contains 0.1463 mg of copper per RACC, it is defined as copper source food based on the CAC per serving. Consuming 6.15 RACCs of the sandwich meets the NRV for copper but results in receiving 3,120 kcal of energy, which is 1,120 kcal more than the DV or DRV for energy. Since the serving of this sandwich based on the proposed method is 76.92 g, and this amount of sandwich contains 0.06 mg of copper, this sandwich is not defined as high copper or copper source food based on the proposed method (Figure 3).

According to the CAC per serving, since copper source foods are determined by employing the high copper amounts of the source claim for copper, some foods that met copper requirements were not appropriate food choices based on

the CAC per serving to achieve adequate copper intake. For example, if raw passion fruit juice (NDB number 9232) contains RACC of 240 mL, 0.133 mg of copper per RACC, and 51 kcal of energy per 100 g, is it defined as high copper or copper source food based on the proposed method and CAC per serving? Since this passion fruit juice contains less than 0.135 mg of copper per RACC, it is not defined as high copper or copper source food based on the CAC per serving. Consuming 1,626.5 mL of passion fruit juice meets the NRV for copper, and this passion fruit juice is customarily consumed 2,400 mL in 10 eating occasions. Since the serving of this passion fruit juice based on the proposed method is 240 mL, and this amount of passion fruit juice contains 0.133 mg of copper, this passion fruit juice is defined as copper source food based on the proposed method.

The average (%) of similarities between the proposed method and the CAC per serving was 84.47% for high copper and copper source foods in food groups. Employing strict criteria of the high and source claims for copper based on the CAC per serving decreased the averages (%) of foods containing appropriate copper levels in 22 food groups (lamb, veal, and game products; snacks; fruits and fruit juices; pork products; beef products; breakfast cereals; vegetables and vegetable products; cereal grains and pasta; baby foods; soups, sauces, and gravies; American Indian/Alaska Native foods; sweets; poultry products; baked products; finfish and shellfish products; nut and seed products; sausages and luncheon meats; meals, entrees, and side dishes; beverages; legumes and legume products; dairy and egg products; restaurant foods) as compared with the proposed method. Also, calculating the copper content of some foods in large amounts (due to not considering the energy content of

Figure 2: Results of cheese quesadilla choice based on the FDA per serving for achieving adequate copper intake.

Figure 3: Results of fish sandwich choice based on the CAC per serving for achieving adequate copper intake.

foods) based on the CAC per serving increased the average (%) of foods containing appropriate copper levels in one food group (fast foods) as compared with the proposed method. For example, the averages (%) of foods containing appropriate copper levels in lamb, veal, and game products, snacks, and fast foods were respectively 28.35%, 20%, and 45.73% based on the CAC per serving and 69.2%, 47.27%, and 26.22% based on the proposed method.

Foods containing appropriate copper levels based on the CAC per 100 g or 100 mL

Since calculating copper content and determining appropriate copper levels based on the CAC per 100 g or 100 mL are performed without considering RACCs, making some food choices based on the CAC per 100 g or 100 mL to achieve adequate copper intake did not meet copper requirements. Employing a fixed food amount of 100 g for one solid food or 100 mL for one liquid food may be high for some foods. Thus, calculating the copper content per 100 g of one solid food or 100 mL of one liquid food based on the CAC may show the copper content of some foods inappropriately high. For example, if ground cinnamon (NDB number 2010) contains RACC of 0.7 g and 0.339 mg of copper per 100 g, is it defined as high copper or copper source food based on the proposed method and CAC per 100 g? Since this cinnamon contains 0.339 mg of copper per 100 g, it is defined as high copper food based on the CAC per 100 g. Consuming 265.5 g of the cinnamon meets the NRV for copper, but this cinnamon is customarily consumed 7 g in 10 eating occasions. Since the serving of this cinnamon based on the proposed method is 0.7 g, and this amount of cinnamon contains 0.002 mg of copper, this

cinnamon is not defined as high copper or copper source food based on the proposed method (Figure 4).

According to the CAC per 100 g or 100 mL, since the copper content of some foods is calculated in small amounts, and the high copper and copper source foods (except liquid foods) are determined by employing the high copper amounts of the high and source claims for copper, some foods that met copper requirements were not appropriate food choices based on the CAC per 100 g or 100 mL to achieve adequate copper intake. Employing a fixed food amount of 100 g for one solid food or 100 mL for one liquid food may be low for some foods. Thus, calculating the copper content per 100 g of one solid food or 100 mL of one liquid food based on the CAC may show the copper content of some foods inappropriately low. For example, if split pea soup (NDB number 6192) contains RACC of 245 g and 0.11 mg of copper per 100 g, is it defined as high copper or copper source food based on the proposed method and CAC per 100 g? Since this soup contains 0.11 mg of copper per 100 g, it is not defined as high copper or copper source food based on the CAC per 100 g. Consuming 818.2 g of the soup meets the NRV for copper, and this soup is customarily consumed 2,450 g in 10 eating occasions. Since the serving of this soup based on the proposed method is 245 g, and this amount of soup contains 0.269 mg of copper, this soup is defined as high copper food based on the proposed method.

Since calculating the copper content and determining appropriate copper levels based on the CAC per 100 g or 100 mL are performed without considering the energy content of foods, making some food choices based on the CAC per 100 g or 100 mL to achieve adequate copper

Figure 4: Result of ground cinnamon choice based on the CAC per 100 g for achieving adequate copper intake.

intake exceed energy needs. For example, if dark corn syrup (NDB number 19349) contains 396.5 kcal of energy per 100 mL, RACC of 30 mL, and 0.0735 mg of copper per 100 mL, is it defined as high copper or copper source food based on the proposed method and CAC per 100 mL? Since this syrup contains 0.0735 mg of copper per 100 mL, it is defined as copper source food based on the CAC per 100 mL. Consuming 1224.9 mL of the syrup meets the NRV for copper but results in receiving 4,857 kcal of energy, which is 2,857 kcal more than the DV or DRV for energy. Since the serving of this syrup based on the proposed method is 30 mL, and this amount of syrup contains 0.02 mg of copper, this syrup is not defined as high copper or copper source food based on the proposed method (Figure 5).

The average (%) of similarities between the proposed method and the CAC per 100 g or 100 mL was 78.1% for high copper and copper source foods in food groups. Calculating the copper content of some foods in large amounts and some other foods in small amounts and employing strict criteria of the high and source claims for copper based on the CAC per 100 g or 100 mL increased the averages (%) of foods containing appropriate copper levels in 11 food groups (spices and herbs; snacks; baked products; sweets; breakfast cereals; cereal grains and pasta; American Indian/Alaska Native foods; nut and seed products; sausages and luncheon meats; fats and oils; beverages) and decreased the averages (%) of foods containing appropriate copper levels in 14 food groups (lamb, veal, and game products; fruits and fruit juices; soups, sauces, and gravies; meals, entrees, and side dishes; pork products; beef products; vegetables and vegetable products; fast foods; restaurant foods; baby foods; poultry products; finfish and shellfish

products; legumes and legume products; dairy and egg products) as compared with the proposed method. For example, the averages (%) of foods containing appropriate copper levels in spices and herbs, snacks, lamb, veal, and game products, and fruits and fruit juices were respectively 83.61%, 80.61%, 37.95%, and 19.59% based on the CAC per 100 g or 100 mL and 0%, 47.27%, 69.2%, and 49.71% based on the proposed method.

Foods containing appropriate copper levels based on the CAC per 100 kcal

Since calculating the copper content and determining appropriate copper levels based on the CAC per 100 kcal are performed without considering RACCs, making some food choices based on the CAC per 100 kcal to achieve adequate copper intake did not meet copper requirements. Employing a fixed energy amount of 100 kcal may be high for some foods. Thus, calculating the copper content per 100 kcal of food based on the CAC may show the copper content of some foods inappropriately high. For example, if carbonated cola or pepper drink (NDB number 14146) contains 1 kcal of energy per 100 g, RACC of 360 mL, and 0.002 mg of copper per 100 g, is it defined as high copper or copper source food based on the proposed method and CAC per 100 kcal? Since this drink contains 0.2 mg of copper per 100 kcal, it is defined as high copper food based on the CAC per 100 kcal. Consuming 44,500 mL of the drink meets the NRV for copper, but this drink is customarily consumed 3,600 mL in 10 eating occasions. Since the serving of this drink based on the proposed method is 360 mL, and this amount of drink contains 0.007 mg of copper, this drink is not defined as high copper or copper source food based on the proposed method (Figure 6).

The average (%) of similarities between the proposed method and the CAC per 100 kcal was 80.85% for high copper and copper source foods in food groups. Calculating the copper content of some foods in large amounts based on the CAC per 100 kcal increased the averages (%) of foods containing appropriate copper levels in all 25 food groups as compared with the proposed method. For example, the averages (%) of foods containing appropriate copper levels in spices and herbs, vegetables and vegetable products,

fruits and fruit juices, and soups, sauces, and gravies were respectively 90.16%, 96.59%, 88.89%, and 78.51% based on the CAC per 100 kcal and 0%, 49.43%, 49.71%, and 48.35% based on the proposed method.

DISCUSSION

Some scientific literature, similar to the proposed method, FDA and CAC per serving, CAC per 100 g, and CAC per 100 kcal, defined liver^{13,14,15,16,17,18,19,20,21,22,23,24},

Figure 5: Results of dark corn syrup choice based on the CAC per 100 mL for achieving adequate copper intake.

Figure 6: Result of carbonated cola or pepper drink choice based on the CAC per 100 kcal for achieving adequate copper intake.

kidney^{15,20}, oyster^{14,15,17,19,20,21,22,23,24,25,26}, lobster^{17,19}, cocoa^{17,19,27}, cocoa-rich chocolate^{15,17,19,20,21,28}, potatoes^{17,29}, Brazil nuts²⁵, cashew nuts^{17,23,25}, hazelnuts²⁵, walnuts²⁵, sesame seeds^{19,23}, peanuts²⁵, soybeans²³, lentils²⁵, kidney beans²⁹, barley²⁵, and oats²⁵ as foods containing appropriate copper levels (to achieve adequate copper intake).

Some scientific literature, similar to the proposed method, FDA and CAC per serving, CAC per 100 g or 100 mL, and CAC per 100 kcal, defined cow milk^{16,17,20,22,30,31,32} and sugar²⁴ as foods containing inappropriate copper levels.

Edmunds and Mayhew²⁵ and Kumar³³, in contrast to the proposed method, FDA and CAC per serving, CAC per 100 g, CAC per 100 kcal, Chang et al.³⁴, and Underwood²⁴, defined honey as food containing an appropriate copper level. Consuming 2,500 g of honey (NDB number 19296; 0.036 mg of copper per 100 g; 304 kcal of energy per 100 g) meets the DV or NRV for copper. However, this honey is customarily consumed 210 g in 10 eating occasions. In addition, consuming 2,500 g of the honey results in receiving 7,600 kcal of energy, which is 5,600 kcal more than the DV or DRV for energy.

Elgailani³⁵, Singh and Singh²³, Tadayon et al.³⁶, and the CAC per 100 kcal, in contrast to the proposed method, FDA and CAC per serving, and CAC per 100 mL, defined tea as food containing an appropriate copper level. Consuming 8,972 mL of brewed black tea (NDB number 14355; 0.01 mg of copper per 100 g; 1 kcal of energy per 100 g) or 21,728 mL of brewed green tea (NDB number 14278; 0.004 mg of copper per 100 g; 1 kcal of energy per 100 g) meets the DV or NRV for copper. However, brewed tea is customarily consumed 3,600 mL in 10 eating occasions.

Cromwell¹⁴, Pizzorno et al.³⁷, CAC per 100 g, and CAC per 100 kcal, in contrast to the proposed method and FDA and CAC per serving, defined yeast as food containing an appropriate copper level. Consuming 206.4 g of yeast (NDB number 18375; 0.436 mg of copper per 100 g; 325 kcal of energy per 100 g) meets the DV or NRV for copper. However, this yeast is customarily consumed 6 g in 10 eating occasions.

The CAC per 100 g and CAC per serving, in contrast to the proposed method, FDA per serving, CAC per 100 kcal, and Bobinaité et al.³⁸, did not define raspberries as a food item containing an appropriate copper level. Consuming 1,000 g of raw raspberries (NDB number 9302; 0.09 mg of copper per 100 g; 52 kcal of energy per 100 g) meets the DV or NRV for copper, and these raspberries are customarily consumed 1,400 g in 10 eating occasions.

The FDA and CAC per serving, in contrast to the proposed method, CAC per 100 g, and CAC per 100 kcal, defined beef empanadas as a food item containing an appropriate copper level. Consuming 928 g of beef empanadas (NDB number 36403; 0.097 mg of copper

per 100 g; 0.136 mg of copper per RACC; 335 kcal of energy per 100 g; RACC of 140 g) meets the DV or NRV for copper but results in receiving 3,108 kcal of energy, which is 1,108 kcal more than the DV or DRV for energy.

CONCLUSIONS

It is well-known that excessive energy intake can lead to overweight or obesity. However, calculating the copper content and determining appropriate copper levels based on the FDA and CAC per serving and CAC per 100 g or 100 mL are performed without considering the energy content of foods. Thus, making some food choices based on the FDA and CAC per serving or CAC per 100 g or 100 mL to achieve adequate copper intake exceeded energy needs, which could lead to overweight or obesity.

RACC values represent the amount (edible portion) of food customarily consumed per eating occasion⁸. However, calculating the copper content and determining appropriate copper levels based on the CAC per 100 g or 100 mL and CAC per 100 kcal are performed without considering RACCs. Thus, making some food choices based on the CAC per 100 kcal or CAC per 100 g or 100 mL to achieve adequate copper intake did not meet copper requirements, which could lead to copper deficiency. Also, according to the CAC per 100 g or 100 mL, since the copper content of some foods is calculated in small amounts, and the high copper and copper source foods (except liquid foods) are determined by employing the high copper amounts of the high and source claims for copper, some foods that met copper requirements were not appropriate food choices based on the CAC per 100 g or 100 mL to achieve adequate copper intake.

According to the CAC per serving, since the copper source foods are determined by employing the high copper amounts of the source claim for copper, some foods that met copper requirements were not appropriate food choices based on the CAC per serving to achieve adequate copper intake.

On the basis of the proposed method, calculating the copper content and determining appropriate copper levels in foods are performed by considering RACCs and the energy content of foods. Thus, making food choices based on the proposed method met copper requirements and did not exceed energy needs. According to the proposed method, RACCs and DVs for copper and energy are used as a reference for calculating copper content and determining appropriate copper levels in foods. Thus, making food choices based on the proposed method without employing the statistical significance is considered a reliable choice (Figure 7).

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Figure 7: Results of food choices based on different methods for achieving adequate copper intake.

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