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Revisión

The nutritional limitations of plant-based beverages in infancy and childhood

Limitaciones nutricionales de las bebidas vegetales en la lactancia y la infancia

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Abstract

Breastfeeding, infant formula and cow's milk are basic foods in infant nutrition. However, they are being increasingly replaced either totally or partially by plant-based beverages.

The composition of 164 plant-based beverages available in Spain was reviewed based on the nutritional labeling of the package and the manufacturers' webpages. This was compared to the composition of cow's milk and infant formula. In addition, the nutritional disease associated with consumption of plant-based beverages in infants and children was reviewed by means of a literature search in Medline and Embase since 1990 based on the key words "plant-based beverages" or "rice beverages" or "almond beverages" or "soy beverages" and "infant" or "child".

The nutritional composition of 54 soy beverages, 24 rice beverages, 22 almond beverages, 31 oat beverages, 6 coconut beverages, 12 miscellaneous beverages and 15 mixed beverages was described. At least 30 cases of nutritional disease in children associated with nearly exclusive consumption of plant-based beverages have been published. A characteristic association has been observed between soy beverage and rickets, rice beverage and kwashiorkor, and almond-based beverage and metabolic alkalosis.

The nutritional quality of plant-based beverages is lower than that of cow's milk and infant formula, therefore they are not a nutritional alternative. Predominant or exclusive use of these beverages in infant feeding can lead to serious nutritional risks. In the case of nonexclusive feeding with these beverages, the pediatrician should be aware of the nutritional risks and limitations of these beverages in order to complement their deficiencies with other foods.

Key words:

Milk substitutes. Beverages. Soy milk. Infant formula. Failure to thrive. Kwashiorkor. Metabolic alkalosis.

Resumen

La lactancia materna, la fórmula infantil y la leche de vaca son alimentos básicos en la nutrición del lactante. Sin embargo, cada vez son reemplazados, total o parcialmente, por bebidas vegetales.

Se ha revisado la composición de 164 bebidas vegetales disponibles en España a partir del etiquetado nutricional del envase y de las páginas web de los fabricantes. Se ha comparado con la composición de la leche de vaca y de la fórmula infantil. Además, se ha revisado la patología nutricional asociada con el consumo de bebidas vegetales en lactantes y niños mediante una búsqueda bibliográfica en Medline y EMBASE desde 1990 basada en las palabras clave "plant-based beverages" o "rice beverages" o "almond beverages" o "soy beverages" y "infant" o "child".

Se describe la composición nutricional de 54 bebidas de soja, 24 bebidas de arroz, 22 bebidas de almendras, 31 bebidas de avena, 6 bebidas de coco, 12 bebidas misceláneas y 15 bebidas mixtas. Se han publicado al menos 30 casos de patología nutricional en niños asociadas con un consumo casi exclusivo de bebidas vegetales. Se ha observado una asociación característica entre la bebida de soja y el raquitismo, la bebida de arroz y el kwashiorkor, y la bebida a base de almendras y la alcalosis metabólica.

La calidad nutricional de las bebidas vegetales es menor que la leche de vaca y la fórmula infantil, por lo que no son una alternativa nutricional. El uso predominante o exclusivo de estas bebidas en la alimentación infantil puede conducir a graves riesgos nutricionales. En el caso de una alimentación no exclusiva con estas bebidas, el pediatra debe ser consciente de los riesgos y limitaciones nutricionales de estas bebidas para complementar sus deficiencias con otros alimentos.

Palabras clave:

Sustitutos de la leche. Bebidas. Leche de soja. Fórmula infantil. Fallo de medro. Kwashiorkor. Alcalosis metabólica.

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INTRODUCTION

Breastfeeding and complementary feeding in the first year of life achieve adequate growth of the child (1). When breastfeeding is not possible or supplements are required, infant formula from cow's milk is recommended. The composition of these formulas must meet nutritional recommendations (2). However, when breastfeeding or formula is replaced by other beverages, serious nutritional consequences may result (3).

The intake of plant-based beverages (PBBs) in the early years of life has increased in recent years (4). The main reasons for this change are preference for plant foods, aversion to the use of cow's milk, and prevention or treatment of cow's milk allergy, as part of strict vegetarian diets or as a consequence of the advice of professionals from alternative medicines (5). Primary use in the early years of life of mainly soy, rice, almond or oat PBBs results in nutritional risks (rickets, failure to thrive, kwashiorkor or metabolic alkalosis, among others) (6). In addition, in our country we reported a case of scurvy with bone fractures in an infant fed almost exclusively with almond beverages (7).

The aim of this study was to review the composition of PBBs marketed in Spain in order to compare them to the nutritional recommendations for infant formulas and to the composition of cow's milk. In addition, publications on nutritional disease associated with consumption of PBBs in children were reviewed in order to determine whether there was a specific type of nutritional disease associated with each type of PBB.

MATERIALS AND METHODS

The composition of 164 brands of PBBs marketed in Spain was reviewed (54 soy beverages, 24 rice beverages, 22 almond beverages, 31 oat beverages, 6 coconut beverages, 12 beverages from other miscellaneous plants [barley, canary grass, hazelnut, hemp, macadamia nut, sesame or spelt] and 15 mixed PBBs [rice and almond, coconut, hazelnut or quinoa, and oat with coconut or almond]). Composition values were taken from the nutritional labels of the PBB packages purchased in stores and from the manufacturers webpages, where the content in kilocalories, carbohydrates, sugars, proteins, total fats and saturated, monounsaturated, and polyunsaturated fatty acids, fiber, salt and supplements, if any, both minerals and vitamins, were specified. The composition of PBBs was compared to the recommended composition of infant formula and soy infant formula (2) and to the composition of cow's milk (8).

In addition, the literature since 1990 on nutritional disease associated with primary intake of PBBs in children was reviewed by means of a search in Medline and Embase based on the key words "plant based beverages" or "rice beverages" or "almond beverages" or "soy beverages" and "infant" or "child".

RESULTS

Table I shows the mean content in kilocalories, macronutrients, percentage of energy/protein, number of brands supplemented with calcium, vitamin D and other minerals and vitamins for each group of PBBs, as well as the recommended composition of soy infant formula, infant formula and composition of cow's milk.

The composition of 54 brands of soy beverages is shown in supplemental table I (http://www.nutricionhospitalaria.org/wp-content/uploads/2014/11/931-material-suplementario.pdf). The mean calorie content was 46.7 ± 13.1 kcal/100 ml. There was no uniformity in their composition as shown by the wide energy range (27-80.7). In 43 of the 54 brands, calorie provision was less than 60 kcal/100 ml. Protein content was 2.1-3.8 g/100 ml. Forty-three brands were supplemented with calcium and 23 of these were also supplemented with vitamin D. The most commonly added amounts were 120 mg of calcium per 100 ml and 0.75 µg of vitamin D per 100 ml. Other vitamins were added in 25 soy beverages, especially B_2, B_{12} and A. Only two of the 55 soy beverages included added minerals, such as iron.

The composition of 24 brands of rice beverages marketed in our country is shown in supplemental table II (http://www.nutricionhospitalaria.org/wp-content/uploads/2014/11/931-material-suplementario.pdf). These beverages had a mean calorie content of 56.8 ± 6.3 kcal/100 ml, with a range from 47 to 68 kcal/100 ml, a low mean protein content of 0.3 ± 0.2 g/100 ml and low fat levels (0.8-2 g/100 ml). Of the 24 brands, only eight specified the added amounts of calcium and only five of these, the added amounts of vitamin D. The percentage of energy provided by proteins was less than 3% in most cases.

The composition of 22 different brands of almond beverages is shown in supplemental table III (http://www.nutricionhospitalaria.org/wp-content/uploads/2014/11/931-material-suplementario.pdf). Almond beverages are hypocaloric and hypoproteic beverages as compared to infant formula and cow's milk. Mean calorie provision was 40.2 ± 14.3 kcal/100 ml, and equal to or less than 60 kcal/100 ml in 19 of the 22 brands studied. Protein content was 0.3-1.6 g/100 ml. Carbohydrate content was intermediate between soy and rice beverages. Of the 22 brands, only five were supplemented with calcium and vitamin D.

Mean content of the rest of beverages studied is shown in supplemental tables IV and V. The group of oat, coconut and miscellaneous beverages comprised 49 brands. Mean calorie content was 44.9 ± 10.7 kcal/100 ml (range 15-65), mostly at the expense of carbohydrates (mean value 6.9 ± 2.5 g/100 ml, range 2-11) and to a lesser extent of fats (mean value 1.4 ± 0.8 g/100 ml, range 0.1-3.6). Mean protein content was low but not as low as for rice beverages (mean value 0.7 ± 0.2 g/100 ml, range 0.1-1.4). Only 13 of these 49 beverages were supplemented with calcium and vitamin D. As shown in table I, the group of six coconut beverages had the lowest calorie content of the PBBs (mean value 33.8 ± 15.1 kcal/100 ml) and a protein content similar to rice beverages (0.2 ± 0.2 g/100 ml). The mixed group of beverages included 15 brands (Supplemental Table VI http://www.nutricionhospitalaria.org/wp-content/uploads/2014/11/931-material-suplementario.pdf). The composition of the 12 mixed beverages containing rice had a higher calorie content at the expense of carbohydrates and to a lesser extent of proteins than mixed oat beverages.

Following the literature review on nutritional disease related to primary intake of PBBs, 20 papers were found reporting 30 clinical cases associated with consumption of soy, rice or almond beverages (Tables II-IV).

Table I. Nutritional composition of plant-based beverages, cow's milk and recommended composition of soy formula and infant formula

Plant-based	Number of brands	Kcal/100 ml (range)	Carbohydrates g/100 ml (range)	Fats g/100 ml (range)	Proteins g/100 ml (range)	Protein energy/Total energy (%)	Supplemented (n)			
							Calcium	Vitamin D	Other minerals	Other vitamins
Soy	54	46.7 ± 13.1 (27-80.7)	4.3 ± 2.9 (0.1-11.8)	1.8 ± 0.4 (0.9-2.9)	3.1 ± 0.4 (2.1-3.8)	28.3 ± 6.9 (20.0-42.0)	43	23	2	25
Rice	24	56.8 ± 6.3 (47-68)	11.5 ± 1.5 (9.4-14.2)	0.9 ± 0.1 (0.8-2)	0.3 ± 0.2 (0.1-0 .8)	2.4 ± 1.4 (0.8-6.4)	8	5	0	2
Almond	22	40.2 ± 14.3 (25-74)	4.4 ± 2.5 (0.1-10.5)	2.0 ± 0.6 (1.1-2.8)	0.8 ± 0.3 (0.3-1.6)	8.0 ± 2.5 (4.3-12.3)	11	5	1	5
Oat	31	45.3 ± 8.3 (30-60)	7.5 ± 1.7 (4.4-11)	1.1 ± 0.4 (0.5-1.8)	0.9 ± 0.3 (0.3-1.4)	8.3 ± 3.1 (3.3-13.7)	16	9	0	5
Coconut	6	33.8 ± 15.1 (15-53)	4.3 ± 2.5 (2-9.1)	1.8 ± 1.1 (0.1-3.3)	0.2 ± 0.2 (0.1-0.5)	3.0 ± 1.9 (1.2-6.3)	2	2	0	2
Miscellaneous	12	48.1 ± 10.2 (29-65)	6.0 ± 3.0 (2.2-10.5)	2.2 ± 0.8 (1-3.6)	0.7 ± 0.3 (0.4-1.1)	6.4 ± 2.6 (5.5-7.1)	1	2	0	1
Mixed	15	61.3 ± 13.0 (36-90)	10.7 ± 2.7 (5.2-14.5)	1.6 ± 0.7 (0.8-3.1)	0.6 ± 0.4 (0.3-1.8)	4.5 ± 3.3 (2.5-10.4)	1	0	0	0

	Kcal/100 ml	Carbohydrates g/100 ml	Fats g/100 ml	Proteins g/100 ml	Protein energy/Total energy (%)
Cow's milk (8)	60-70	4.5-5.0	3.5-4.0	3.2	18.2-21.3
Soy infant formula (2)	60-70	5.8-9.1	2.8-3.9	1.5-1.9	7.4-10.6
Infant formula (2)	60-70	5.8-9.1	2.8-3.9	1.2-1.9	7.4-10.6

Table II. Published clinical cases of nutritional problems associated with soy beverages consumed by infants and toddlers

Authors Year	Reasons for introduction of soy beverage	Age of introduction of soy beverage (age of diagnosis)	Characteristics of feeding	Daily intake	Laboratory findings	Diagnosis
Carvalho NF et al. (6) 2001	Taste preference Breastfeeding without vitamin D supplement	10 months (17 months)	Soy beverage, vegetables, fruits	900 ml	Ca 2.22 mmol/l P 0.55 mmol/l AP 1879 U/l VitD 19.2 nmol/l PTH 12.1 pmol/l	Rickets Failure to thrive
Fox AT et al. (16) 2004	Breastfeeding without vitamin D supplement Urticaria with infant formula at 6 months	6 months (14 months)	Breastfeeding, soy beverage, vegetables, fruits	--	Ca 1.71 mmol/l P 1.06 mmol/l AP 2054 U/l VitD 15 nmol/l PTH 44.1 pmol/l	Rickets Failure to thrive Ferropenic anemia
Imataka G et al. (17) 2004	Eczema at 3 weeks Parental decision	1 month (5 months)	Soy beverage Calcium: 28.9 mg/l No vitamin D	--	Ca 1.32 mmol/l P 1.6 mmol/l AP 2303 U/l VitD 19.9 nmol/l PTH 254 pmol/l	Hypocalcemic tetany Rickets Failure to thrive

AP: Alkaline phosphatase; Ca: Calcium; P: Phosphorus; PTH: Parathyroid hormone; VitD: 25-OH-vitamin D_3.

COMMENTS

COMPOSITION OF PBBs

Rice beverages were the PBBs with the highest energy content, although their mean value was lower than the minimum value of infant formula or cow's milk (60 kcal/100 ml). The rest of the PBB groups had a mean value lower than 50 kcal/ml. Thus, almond beverages and coconut beverages had a mean calorie content of 40 and 33 kcal/100 ml, respectively. Only mixed beverages, most of which contain rice, had a higher calorie content.

Overall analysis of all PBB groups showed that soy beverages had the highest protein content. However, the nutritional value of soy protein is limited by the content in methionine and cysteine, with a lowest digestible indispensable amino acid score (DIASS) value of 90.6%, based on the biological value and true ileal amino acid digestibility (9). The rice protein isolate also has a DIASS value of 37.1% (10). Regarding the rest of plants used in PBBs, no information was available about the DIASS of their proteins (4). However, the value of the protein digestibility-corrected amino acid score (PDCAAS) is known. The PDCAAS values of the raw materials used in some commercial PBBs are 67.7% (quinoa), 63-66% (hemp), 45-60% (oat), 54% (rice) and 30% (almond) (11). Consequently, infant formula, milk and other dairy products have higher value protein than PBBs.

With regard to carbohydrates, in most PBBs over 70% are sugars. According to the European regulation on nutritional labeling, sugars include monosaccharides and disaccharides but not polyols or starch (12). Formula intended for infants under 4-6 months should not contain fructose or sucrose (2) On the other hand, PBBs do not contain lactose. Lactose is considered to provide beneficial effects for gut physiology, including prebiotic effects, softening of stools, and enhancement of calcium absorption (2). In this regard, the 2014 EFSA proposal recommends that infant formula contains a minimum of 4.5 g/100 kcal of lactose (13). Fiber content was less than 0.5 g/100 ml in most cases (64 of 113 PBBs).

With regard to fats, only soy beverages had a profile with a clear predominance of polyunsaturated fatty acids, but their overall fat content was very low (1.8 ± 0.4 g/100 ml) as compared to the recommended total fat content of 2.8-3.9 g/100 ml in infant formulas, equivalent to about 40-54% of energy content, which is similar to values found in human milk. In almond beverages, the predominant fats were monounsaturated fatty acids, while in coconut beverages, saturated fatty acids were predominant. In all cases, mean fat content values were lower than for infant formula and cow's milk. Thus, fat content values were very low in rice and oat beverages (mean value 1 g/100 ml) and low (mean value 1.5-2 g/100 ml) in the rest of PBBs (Table I). Furthermore, no information was available about the minimum content in linoleic acid, erucic acid or the maximum values of trans fatty acids, among others (2).

With regard to minerals, divalent cations like zinc, magnesium and iron are bound by phytates present in all seeds, reducing their bioavailability (14).

Table III. Published clinical cases of nutritional problems associated with rice beverages consumed by infants and toddlers

Authors Year	Reasons for introduction of rice beverage	Age of introduction of rice beverage (age of diagnosis)	Characteristics of feeding	Daily intake	Laboratory findings	Diagnosis
Massa G et al. (24) 2001	Dermatitis unimproved with a soy formula (homeopathic physician)	16 weeks (33 weeks)	Rice beverage Fruits, vegetables	RB: 1.0-1.38 l	Alb 26 g/l	Kwashiorkor
Carvalho NF et al. (6) 2001	Eczema and perceived milk intolerance	13-15 months? (22 months)	Rice beverage Vegetables	RB: 1.5 l 0.3 g prot/kg/d 79 kcal/kg/d	Alb 10 g/l Zinc 32.2 µg/dl	Kwashiorkor
Liu T (25) 2001	Perceived intolerance of formula	? (4 months)	Rice beverage Vitamins	--	Alb 14 g/l TProt 29 g/l Zinc 22 µg/dl	Kwashiorkor
Novembre E et al. (26) 2003	Atopic dermatitis (naturopathic doctor)	5 months (6 months)	Rice beverage, rice cream, vegetables, fruits	RB: 660 ml 0.5 g prot/kg/d 86 kcal/kg/d	Alb 14 g/dl TProt 28 g/l	Kwashiorkor
Kuhl J et al. (27) 2004	Atopic dermatitis positive RAST to multiple foods	14 months (17 months)	Rice beverage, 1-2 tablespoons of baby food	5 g prot/d 600 kcal/d	Alb 12 g/l TProt 35 g/l Zinc 27 µg/dl	Failure to thrive Kwashiorkor
Katz K et al. (28) 2005	Breastfed 8 m Rejection of infant formula	8 months (14 months)	Rice beverage, meat, vegetables	--	Alb 14 g/l TProt 36 g/l Zinc 28 µg/dl	Kwashiorkor
Katz K et al. (28) 2005	Rejection of infant formula	2 months (7 months)	Rice beverage, baby food, iron supplementation	--	Alb 15 g/l TProt 34 g/l Zinc 31 µg/dl	Failure to thrive Kwashiorkor
Barreto-Chang OL et al. (29) 2010	Cow's milk allergy	13 months (16 months)	Rice milk (0.4 g proteins/100 ml)	--	VitD 9 nmol/l PTH 20.4 pmol/l	Failure to thrive Rickets
Tierney E et al. (30) 2010	Scalp rash	4 months (8 months)	Rice milk, bananas, sweet potatoes	--	Alb 20 g/l TProt 37 g/l Zinc 91.5 µg/dl	Kwashiorkor
Diamanti A et al. (31) 2011	Cow's milk allergy (3 cases)	3 months (4 months) 1.5 months (4 months) 3 months (5 months)	Rice beverage	--	Alb < 20 g/l TProt < 40 g/l	Kwashiorkor

(Continue in the next page)

Table III (Cont.). Published clinical cases of nutritional problems associated with rice beverages consumed by infants and toddlers

Authors Year	Reasons for introduction of rice beverage	Age of introduction of rice beverage (age of diagnosis)	Characteristics of feeding	Daily intake	Laboratory findings	Diagnosis
Keller MD et al. (32) 2012	Eczema. Allergy to cow's milk, soy, egg, peanut, etc.	13 months (19 months)	Rice beverage, rice, potatoes, carrots	--	Alb 16 g/l TProt 33 g/l	Kwashiorkor
Keller MD et al. (32) 2012	Suspected cow's milk allergy (eczema, vomiting)	12 months (16 months)	Rice beverage Lentils, chick-peas, olives	--	Alb 12 g/l Hb 7 g/dl	Kwashiorkor Anemia
Fourreau D et al. (33) 2013	Suspected cow's milk allergy (naturopathic doctor)	7 months (9 months)	Rice beverage (0.1 g prot/100 ml), fruits, vegetables	RB:800-900 ml	Alb 7 g/l Hb 10 g/dl	Kwashiorkor Anemia
Fourreau D et al. (33) 2013	Suspected cow's milk allergy (parental decision)	13 months (14.5 months)	Rice beverage	RB: 300 ml	Alb 7 g/l Hb 3.5 g/dl Vit B_{12} 143 ng/l	Failure to thrive anemia
Le Louer B et al. (5) 2014	Vomiting	2 months (4.5 months)	Rice beverage	--	Hb 5.7 g/dl Alb 1.8 g/dl Zinc 3.5 μmol/l	Failure to thrive anemia
Le Louer B et al. (5) 2014	Eczema	1 months (7 months)	Rice beverage	--	Hb 8.7 g/dl Alb 1.98 g/dl Zinc 3.9 μmol/l	Failure to thrive Kwashiorkor Anemia
Mori et al. (34) 2015	Atopic dermatitis (naturopathic doctor)	4 months (6 months)	Rice milk, fruits, rice poultry and vegetable broth.	--	Alb 13 g/l TProt 30 g/l Hb 5.7 g/dl	Kwashiorkor Anemia

Alb: Albumin; Hb: Hemoglobin; PTH: Parathyroid hormone; RB: rice beverage; TProt: total protein; VitD: 25-OH-vitamin D_3.

Table IV. Published clinical cases of nutritional problems associated with almond beverages consumed by children

Authors Year	Reasons for introduction of almond beverage	Age of introduction of almond beverage (Age of diagnosis)	Characteristics of feeding	Daily intake	Laboratory findings	Diagnosis
Kanaka C et al. (36) 1992	Eczematous reaction to cow's milk formula (maternal decision)	2.5 months (7.5 months)	Self-prepared extract of almonds Cereals Fruits	98% DRI proteins 54% DRI energy	TSH 378 µlU/ml Iodine 47 nmol/l Free carnitine 12 µmol/l	Failure to thrive Iodine and carnitine deficiency
Mesa O et al. (37) 2009	--	Birth (31 days)	Almond beverage	--	Cl- 94 mmol/l Na+ 136 mmol/l K+ 3 mmol/l CO_3H- 40.3 mmol/l	Dehydration Metabolic alkalosis
Mesa O et al. (37) 2009	--	Birth (4 months)	Almond beverage	--	Cl- 74 mmol/l Na+ 124 mmol/l K+ 2.2 mmol/l CO_3H- 49.8 mmol/l	Metabolic alkalosis
Fourreau D et al. (33) 2013	Suspected gastro-esophageal reflux	12 months (13 months)	Almond beverage (17 mg sodium/100 ml; 24 mg chloride/100 ml) Yogurt Vegetables	840 ml	Cl- 69 mmol/l Na+ 127 mmol/l K+ 1.9 mmol/l CO_3H- 48 mmol/l	Metabolic alkalosis
Doron D et al. (38) 2013	Diarrhea and vomiting attributed by the mother to cow's milk protein allergy	4 months (6 months)	Almond-based home made "formula" (Almond 10 g/water 100 ml)	1,000 ml	Ca 1.4 mmol/l P 1.2 mmol/l AP 818 U/l vitD < 12 nmol/l PTH 30.3 pmol/l Hb 7.7 g/dl	Failure to thrive Rickets Anemia
Doron D et al. (38) 2013	Rash	4-5 months (8 months)	Almond-based and honey home made "formula" (20 gr almonds / 100 ml water)	600 mL	Alb 20 g/l TProt 36 g/l	Kwashiorkor
Le Louer B et al. (5) 2014	Gastro-esophageal reflux, eczema	3.5 months (5 months)	Almond and chestnut beverage	-	Alb 19.5 g/l Ca 0.64 mmol/l Zinc 7 µmol/l	Hypocalcemic tetany Malnutrition

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Table IV (Cont.). Published clinical cases of nutritional problems associated with almond beverages consumed by children

Authors Year	Reasons for introduction of almond beverage	Age of introduction of almond beverage (Age of diagnosis)	Characteristics of feeding	Daily intake	Laboratory findings	Diagnosis
Le Louer B et al. (5) 2014	Parental decision	8.5 months (16.5 months)	Almond and walnuts beverage	--	VitD < 12.5 nmol/l Ca 2.32 mmol/l P 1.71 mmol/l PTH 8.8 pmol/l	Rickets
Ellis D et al. (39) 2015	Tourette syndrome (1 case) Lactose intolerance (2 cases)	3 years 9 years 10 years	Almond milk and varied diet	700-1,000 ml	Urine oxalate 53.5, 81.5 and 97.9 mg/1.73 m^2/d (27.6-35.4)	Hyperoxaluria Hematuria (2 cases) Kidney stones (1 case)
Vitoria I et al. (7) 2016	Medical indication (atopic dermatitis)	2.5 months (11 months)	Almond milk Almond flour Cereals	840 ml/d	Ascorbic acid < 10 µmol/l VitD 31 nmol/l	Scurvy

Alb: Albumin; Ca: Calcium; Hb: Hemoglobin; P: Phosphorus; TProt: total protein; VitD: 25-OH-vitamin D_3.

Processing treatments to prepare PBBs such as flaking, blanching, hot grinding and ultra-high temperature treatment could cause loss of vitamins (15). Therefore, the addition of minerals and vitamins after processing is important. Of the 164 PBBs in the present study, calcium and/or vitamin D were added in over half of the beverages, both other minerals and vitamins were added in only 43 cases.

CONSUMPTION OF PBBs AND NUTRITIONAL DISEASE

The nutritional disorder most often associated with consumption of soy beverages in small children is rickets and failure to thrive, along with ferropenic anemia in some cases (6,16,17) (Table II). In the published cases, soy beverages were mostly given for suspected allergy to cow's milk proteins or due to the parents' belief that it was more suitable for their child. The age of the patients ranged from five to 17 months. The interval between the start of soy beverage consumption and diagnosis of rickets was from four to eight months, depending on the age at which consumption was started. The case reported by Imataka G et al. (10) began to take soy beverage at one month of age and developed hypocalcemic tetany.

According to ESPGHAN, for soy protein infant formula, only protein isolates should be used, and the minimum protein content required by European legislation is higher than that of cow's milk protein infant formula (2.25 g/100 kcal *vs* 1.8 g/100 kcal) (1.5 to 1.2 g/100 ml) to account for potentially lower digestibility and, therefore, lower bioavailability of soy protein compared with intact cow's milk protein. According to the Committee on Nutrition of the American Academy of Pediatrics, the protein of the soy formula must be a soy isolate supplemented with L-methionine, L-carnitine and taurine to provide a protein content of 2.45 to 2.8 g per 100 kcal (1.65 to 1.9 g/100 ml), and phytases can be used (18). Mean protein content of soy beverages in this study was 3.1 ± 0.4 g/100 ml, but the soy proteins of soy beverages were not supplemented with amino acids. For these reasons and despite being the PBBs with the highest mean protein content, their consumption in small children is probably associated with failure to thrive.

The reasons why a diet rich in non-supplemented soy beverage

Table V. Types of plant-based beverages in infants and risk of nutritional disease

Plant-based beverage	Primary associated nutritional disease	Other associated disease
Soy	Rickets	Failure to thrive
Rice	Kwashiorkor	Failure to thrive Anemia
Almond	Metabolic alkalosis	Rickets Hyperoxaluria Scurvy

is a determining factor for rickets are related to calcium and vitamin D. Thus, regarding the calcium added, it depends on the type of salt used. The tricalcium phosphate present in many soy beverages supplemented with calcium is absorbed in a proportion of 75% to the calcium of cow's milk, whereas calcium carbonate has better absorption (19). In addition, heat treatment of commercial soy beverages precipitates the calcium (20), which is the reason for the large difference in calcium content depending on whether the sample is shaken or not (21). The absence of lactose and higher content in insoluble fiber also reduces calcium absorption (22). Moreover, when the type of vitamin D added is specified, it is vitamin D_2, which has lower effectiveness than vitamin D_3 (23). Of the 54 brands studied, only 23 (42%) were supplemented with calcium and vitamin D.

Regarding the clinical manifestations secondary to the use of rice beverages, the information on 17 cases is given in supplemental table IV (http://www.nutricionhospitalaria.org/wp-content/uploads/2014/11/931-material-suplementario.pdf) (5,6,24-34). The principal nutritional consequence in infants of consumption of rice beverages instead of infant formula is protein malnutrition or kwashiorkor, reported in 14 of 17 cases, with clinical data of hypoalbuminemia, edema and rash. Kwashiorkor is a known case of failure to thrive and growth delay in developing countries. However, it is exceptional in developed countries. In the majority of published cases, rice beverage was given for suspected allergy to cow's milk protein. The age of patients at diagnosis ranges from four to 22 months. In ten of 17 cases, consumption of rice beverage was started at four months or earlier. The interval between the start of consumption of rice beverage and diagnosis of kwashiorkor ranged from one to nine months.

The cause of kwashiorkor is the higher calorie content of rice beverages with a very low protein content (0.1-0.8 g/100 ml), which results in proteins accounting for 2.4 ± 1.4% of energy, a significantly lower amount than the percentage of protein provided by breastmilk (5-6%) or infant formula (7-9%) (35). Of the different PBBs, the lowest value of the percentage of energy provided by proteins was that of rice beverages, followed by coconut beverages, which may have the same nutritional risk (Table I). In contrast with these data, children who develop marasmus have a deficient intake of both energy and proteins. The higher calorie provision of rice beverages was due the higher content in carbohydrates (9.4-14.2 g/100 ml). In addition, rice beverages contain no vitamins and are deficient in iron (0.07 mg/100 g) and calcium (0.9 mg/100 ml) (19), unless it is added. Only five of 24 brands of rice beverages were supplemented with calcium and vitamin D.

The clinical manifestations secondary to the use of almond beverages in small children are shown in table IV. Of the ten reported cases (5,7,33,36-39), metabolic alkalosis was noted in three. Since 1980, cases have been reported of similar conditions of hypochloremic and hypokalemic metabolic alkalosis in infants fed with milks lacking sodium chloride (40,41). In the case of almond beverages, the problem is the low chloride content. Thus, the French Food Safety Agency (ANSES) (42) determined that the cause of a case (33) was the low chloride content of the almond beverage (2.4 mg/100 ml). The lower amount of chloride anion due to the lack of intake leads to proximal tubular reabsorption of the bicarbonate anion together with the sodium anion, causing metabolic alkalosis (36). Although the composition stated on the packages is incomplete, according to Doron (38), they contain 0.4 mg sodium per 100 ml and 0.32 mg iron per 100 ml, much lower amounts than those recommended for infant formula.

Almond beverages may also be responsible for severe rickets (38), which may be accompanied by seizure-inducing hypocalcemia. Other authors have reported three cases of hyperoxaluria in children aged three to eight years who took more than 500 ml daily of almond beverages. One of them had kidney stones. The cause is the higher content in oxalates of almond beverages, particularly if they are obtained from homemade almond milk (39). A case of scurvy has also been reported in an 11-month-old infant who took almond beverage and almond flour prescribed by a physician for dermatitis. The scurvy caused fractures of the femur, irritability and failure to thrive (7).

Aside from the cases reported from ingestion of a soy beverage, rice beverage or almond beverage, attention should be given to combinations of different seeds, such as rice, almonds, quinoa, oats, coconut, etc. (Supplemental Table VI http://www.nutricionhospitalaria.org/wp-content/uploads/2014/11/931-material-suplementario.pdf). In fact, it seems there are now published cases of children who consumed these beverages exclusively in the first months of life. For instance, the case of a 2.5-month-old infant who consumed a beverage containing chestnuts, soy, almonds and nuts, and developed malnutrition with hypotonia and somnolence with severe hyponatremia and hypopotasemia (33).

This study has a number of limitations. Despite including 164 types of PBBs in our country, new products are continually appearing. The nutritional information extracted from the labels or manufacturers' webpages does not include information about nutrient bioavailability or information about nutrients covering less than 15% of daily recommended allowances.

SUMMARY

Plant-based beverages are inappropriate alternatives to breast milk, infant formula or cow's milk in the first years of life as they are low in calories, protein, fat, lactose and vitamins. In the case of older children with nonexclusive feeding with PPBs, the pediatrician should be aware of the nutritional risks and limitations of these beverages in order to complement the deficiencies with other foods (43). According to the literature review, nearly exclusive consumption of any kind of PPB is associated with a specific type of disease (Table V). Thus, soy beverages non-supplemented with vitamins or minerals primarily cause rickets and failure to thrive. Rice beverages primarily cause kwashiorkor, associated with failure to thrive or anemia. Almond beverages can cause severe metabolic alkalosis, though cases of rickets, hyperoxaluria or scurvy have also been reported.

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