Croatian Journal of Food Science and Technology
journal homepage: www.ptfos.unios.hr/cjfst/

Original scientific paper *DOI: 10.17508/CJFST.2020.12.1.12*

Development and nutritional evaluation of a complementary diet from fermented provitamin-a-biofortified maize (*Zea mays* L.) and germinated lentil seeds (*Lens culinaris*)

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ARTICLE INFO

Article history:
Received: December 19, 2018
Accepted: September 24, 2019

Keywords:
lentil seed
fermentation
physicochemical
amino acid profile

ABSTRACT

Breast milk often becomes insufficient to meet the nutritional needs of infants from 6 months onwards, and thus there is a need to introduce complementary diets. This study aimed at formulating complementary diets by combining fermented provitamin A biofortified maize flour with germinated lentil flour in ratios of 100%, 90:10%, 80:20% and 70:30%. They were evaluated for proximate composition, functional properties, mineral composition, carotenoid content, anti-nutrient content, amino acid profile and organoleptic properties. The protein contents ranged from 10.65 to 28.17%, 100%; germinated lentil flour (O6R) had the highest value, while the energy values of the diets ranged from 395.62 to 404.13 Kcal/100 g. The foaming capacity, foaming stability, water absorption capacity and bulk density increased, while the oil absorption capacity and dispersibility decreased as the lentils increased. The swelling capacity ranged from 39.92 to 69.42 %. The viscosity increased as the temperature dropped. The potassium and calcium contents increased with increased in the addition of lentils. Sodium and iron contents were high in the sample AM4 (fermented 100% provitamin A biofortified maize). The carotenoid content ranged from 0.80 to 1.27 mg/100 g. The anti-nutritional contents (phytate and oxalate) were reduced, while the trypsin inhibitor increased. The most abundant essential amino acid was leucine, while glutamic acid was the most abundant non-essential amino acid. It was observed that as lentil seed increased, the amino acids increased too. The values obtained for essential amino acid met up with the recommended standards, except for tryptophan, methionine, threonine and cystine. The sample TU1 (70% fermented provitamin A biofortifed maize and 30% germinated lentils seed) was the most acceptable by the panelists compared to the commercial baby formula (control). Therefore, this complementary diet may serve as means to combat protein-energy malnutrition in infants. A further research should be carried out on in-vivo study of this complementary diet.

Introduction

The most popular complementary food fed to infants in Nigeria is a fermented cereal gruel called 'Pap', 'Akamu' or 'Ogi', which is generally perceived by mothers as easy to digest (Onofiok and Nnanyelugo, 1998; Ibeanu and Okeke, 2001). Vitamin A deficiency (VAD) continues to impose a major health issue in the developing world. Vitamin A deficiency affects more than 127 million preschool children (West, 2002; Humphrey et al., 1992). Improving the vitamin A status of young children in developing countries reduces child death rates by 20–50% (Beaton et al., 1993). Also, Pillay et al. (2011) suggested that provitamin A- biofortified maize has the potential to succeed as a new strategy in dealing with the problem of vitamin A deficiency, especially in preschool children. With an attempt to combat VAD, maize (*Zea mays* L.) is one of the six staple crops that have been

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targeted for biofortification with provitamin A carotenoids by the HarvestPlus Challenge Programme (Tanumihardjo, 2008). Provitamin A biofortified maize is an essential source of various major phytochemicals such as carotenoids, phenolic compounds, and phytosterols (Jiang and Wang, 2005; Kopsell et al., 2009; Lopez-Martinez et al., 2009). Lentil seeds (*Lens culinaris*) are pulse that contain high levels of protein (20%–30%), minerals (2%–5%), vitamins (folates), and prebiotic carbohydrates (Bhatty, 1988; Thavarajah et al., 2009; Thavarajah et al., 2015). Protein energy malnutrition, which is widespread in both rural and urban communities in developing countries like Nigeria, generally occurs during the crucial transitional phase when children are weaned from liquid to semi solid foods (Okorie and Ekwe, 2017). During this period of growth, children need nutritionally balanced, calorie-dense complementary foods in addition to breast milk. However, vegetable proteins complementing each other, a combination of legumes and cereal proteins will have a nutritional value as an animal protein (Latham, 1997). Many researches had been done using cereals and legumes for complementary diets. However, there is little information about the combination of provitamin A biofortified maize seeds and lentil seeds for a complementary food. Therefore, this research is aimed at producing a complementary diet from fermented provitamin A biofortified maize and germinated lentils.

Materials and methods

The provitamin A biofortified maize hybrid seeds were obtained from the International Institute of Tropical Agriculture (IITA) at Ibadan, Oyo State and the brown lentil seeds were purchased in Lagos State. The commercial baby formula (Nestle-Cerelac-Maize-Soyabean Infant Cereal, 200 g) served as control was purchased from NAO Supermarket in Akure, Ondo State, and all used chemical reagents were of an analytical grade.

Preparation of fermented provitamin A biofortified maize flour

The fermented provitamin A biofortified maize flour was produced according to the method of Adeniyi et al., (2014). The provitamin A maize seeds were cleaned, sorted, soaked in tap water in the ratio of 1:3 (w/v) for 8 h, fermented at room temperature (25 °C) for 48 h and decanted. They were washed, wet-milled with an attrition mill, sieved and allowed to settle to remove the water. The thick sediment was dried in the oven at 60 °C for 24 h, cooled, packaged in an airtight polyethene bag and plastic container and stored for further use.

Preparation of germinated lentil seeds

The germinated lentil seeds were prepared according to the method of Ndagire et al. (2015) with a little modification. The lentil seeds were cleaned, sorted, steeped in portable water for about 10 hr at an ambient temperature. After decanting the steeping water, they were germinated for 48 hours, after which they were thoroughly washed and air dried to terminate sprouting. They were dried in the oven at 60 °C for 24 h and then winnowed to remove the hull and sprouts. Thereafter, they were milled to fine flour and sieved and then packaged into polyethylene nylon and put inside a plastic container for further use. The formulation of the complementary blends is shown in Table 1.W2F represented unfermented provitamin A biofortified maize flour, and NR8 was the commercial infant formula (control).

Proximate composition

Proximate composition of the formulated blends was determined (crude protein, fat, ash, crude fibre and moisture content) according to the methods of AOAC (2005). Carbohydrate was calculated by difference and the energy value by Atwater's conversion factors.

Table 1. Formulation of blends for a complementary diet from fermented provitamin A maize flour and germinated lentil flour

Samples	Fermented provitamin A biofortified maize flour %	Germinated lentils seed flour %	Unfermented provitamin A biofortified maize flour %	Commercial infant formula %
AM4	100	-	-	-
L9G	90	10	-	-
TU1	80	20	-	-
7QZ	70	30	-	-
W2F	-	-	100	-
NR8	-	-	-	100

AM4 – 100% fermented provitamin A biofortified maize flour; L9G – 90% fermented provitamin A biofortified maize flour: 10% germinated lentil flour; TU1 – 80% fermented provitamin A biofortified maize flour: 20% germinated lentil flour; 7QZ – 70% fermented provitamin A biofortified maize flour: 30% germinated lentil flour; W2F-100% unfermented provitamin A biofortified maize flour; NR8- 100% commercial infant formula.

Functional properties

Bulk density was determined by Nwanekezi et al. (2001), swelling capacity was determined according to the method of Crosbie (1991), water absorption capacity and oil absorption capacity were done by the method of Elkhalifa et al. (2005), foaming capacity and stability was determined by the method of Naranyana and Narasinga-Rao (1982), dispersibility was done using the method of Kulkarni et al. (1991). Viscosity was determined by Ikegwu et al. (2009).

Mineral composition

The method described by AOAC (2005) was used for the mineral analysis. The samples were ashed at 550 °C. The ash was boiled with a 10 ml of 20% hydrochloric acid in a beaker and then filtered into a 100 ml standard flask. This was made up to the mark with deionized water for the minerals to be determined from the resulting solution. Sodium (Na) and Potassium (K) were determined using standard flame emission photometer. Calcium (Ca) and Iron (Fe) were determined using the Atomic Absorption Spectrophotometer (AAS Model SP9).

Carotenoid content

Carotenoid content was determined according to the method described by Palmer et al. (2016).

Antinutrient content

Phytate was determined according to the method of Nkama and Gbenyi (2001), tannin was determined using the method of Makkar and Goodchild (1996), trypsin inhibitor and oxalate were determined by the method of Day and Underwood (1986).

Amino acid profile

The Amino Acid profile of blends was determined using methods described by Benitez (1989). The sample was dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and loaded into the Applied Biosystems Model 120A PTH Amino Acid Analyzer. Tryptophan was determined by the method of AOAC (1998).

Sensory evaluation

Sensory evaluation was carried out using 30 untrained panelists comprising of women (mothers). Nine points hedonic scale was used for appearance, aroma, taste, mouth-feel, and overall acceptability, with 9 indicating “liked extremely” and 1 indicating “disliked extremely”.

Statistical Analysis

All data were analyzed using SPSS (Statistical Package for Social Sciences) version 16.0. The standard error of means and the analysis of variance (ANOVA) were carried out. Means were separated using the Duncan Multiple Range Test (DMRT) at 5% level ($p \leq 0.05$) (Duncan, 1955).

Results and discussion

Proximate composition of the complementary diets from fermented provitamin A maize and germinated lentil seeds

The proximate composition of samples of the flour blends and the 100% germinated lentil flour are presented in Table 2. The moisture content ranged from 4.88 to 8.87 %. There was no significant difference ($p \leq 0.05$) observed in the moisture content of all the samples except for the sample O6R that had high value. This agrees with Sodipo and Fashakin (2011) that reported low moisture content for a complementary diet prepared from germinated maize, cowpea and pigeon pea. The values obtained met the required standard for weaning food (FAO/WHO, 1985). Low moisture content in food samples increased the storage period of the food products (Alozie et al., 2009). The ash content ranged from 0.48 to 5.00 %. All the samples met the recommended ash content by WHO/FAO (2004) in the complementary diet of less than 5 g/100 g. However, this was not in agreement with with the results of the study by Fikiru et al. (2016) that reported the range of 1.5 to 2.5 % for complementary food blended from maize, roasted pea and malted barley. The crude fibre content ranged from 0.68 to 1.81 %, with the 100% germinated lentil flour had the highest. There was a significant difference in all the samples and the values obtained were low. It may be due to the fermentation and germination of the used processes. This was in accordance with the daily recommended allowance of less than 5% for crude fibre in the complementary diet (FAO/WHO, 1985).

The protein content ranged from 10.65 to 28.17 %. There was a significant difference in all the samples. It was observed that as the amount of lentils increased, the protein content increased. This is in agreement with other findings that processing techniques, such as germination, improved the nutritional quality of the food products, particularly in terms of protein content (Fasasi et al., 2004), and in accordance with the report of Sodipo and Fashakin (2011) and Fikiru et al. (2016) that observed increased protein content. The samples O6R, TU1 and

7QZ met up with the recommended standard of ≥15% (FAO/WHO, 1991), while the samples AM4 and L9G were lowered due to the fact that no or small quantity of legume was added respectively. The values obtained for fat content ranged from 5.67 to 11.66 %. There was a significant difference in the obtained values except for the sample TU1 and 7QZ that were not significantly different. The sample O6R had the highest value, probably due to fact that it was of 100% germinated lentil flour. This did not agree with the daily recommended standard in the range from 10 – 25% (WHO/FAO, 2004). The fat content increased in the blend samples as the amount of germinated lentil flour increased, probably due to the fact that lentil seed was added. The carbohydrate content ranged from 40.50 to 77.23 % with a significant difference in all the samples. The sample AM4 had the highest value because it was pure (100%) fermented provitamin A biofortified maize. The obtained results agreed with the recommended value of ≥ 65g/100g (WHO/FAO, 2004). The energy value ranged from 395.62 to 404.13 Kcal/100 g. The highest value was obtained in the sample 7QZ, perhaps because of the high amount of the germinated lentil flour that supplemented the fermented provitamin A maize flour. The obtained values are in accordance with the recommended energy content by WHO/FAO (2004) of 400 – 425 Kcal/100 g in complementary foods.

Table 2. Proximate composition of the complementary diets from fermented provitamin A biofortified maize and germinated lentils

Sample	Moisture (%)	Ash (%)	Crude fibre (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Energy (Kcal/100 g)
AM4	4.88±0.32^{b}	0.48±0.01^{c}	1.09±0.10^{b}	10.65±0.01^{e}	5.67±0.30^{d}	77.23±0.30^{a}	402.55
L9G	5.75±1.04^{b}	0.63±0.24^{c}	0.88±0.10^{c}	11.57±0.05^{d}	5.90±0.20^{c}	75.27±0.20^{b}	400.46
TU1	5.90±0.80^{b}	0.96±0.15^{b}	1.01±0.03^{bc}	15.27±0.01^{c}	6.30±0.30^{b}	70.56±0.30^{d}	400.02
7QZ	5.71±0.68^{b}	0.49±0.01^{c}	0.68±0.10^{d}	15.63±0.01^{b}	6.33±0.02^{b}	71.16±0.83^{c}	404.13
O6R	8.87±0.03^{a}	5.00±0.20^{a}	1.18±0.04^{a}	28.17±0.16^{a}	11.66±0.05^{a}	44.55±0.33^{a}	395.62

Values in column with the same superscript are not significantly different ($p \leq 0.05$). Means ± standard deviations of triplicate values. AM4: 100% Fermented provitamin A biofortified (FPVAB) maize flour; L9G – 90% fermented provitamin A biofortified maize flour: 10% germinated lentil flour; TU1 – 80% fermented provitamin A biofortified maize flour: 20% germinated lentil flour; 7QZ – 70% fermented provitamin A biofortified maize flour: 30% germinated lentil flour; O6R: 100% germinated lentil flour.

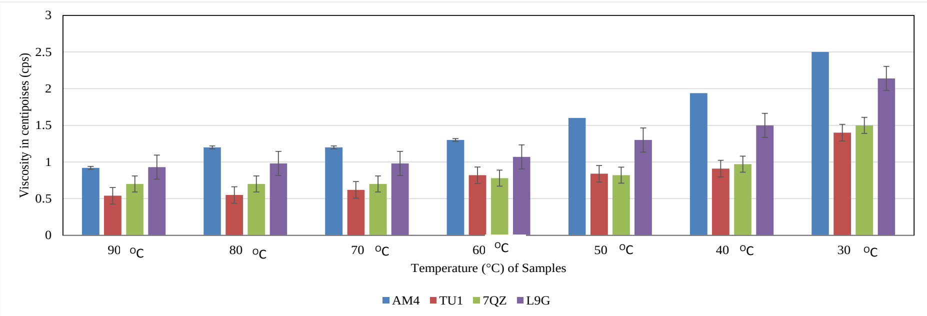

Fig. 1. Viscosity of complementary diets from provitamin A biofortified maize and germinated lentils. AM4: 100% Fermented provitamin A biofortified (FPVAB) maize flour; L9G – 90% fermented provitamin A biofortified maize flour: 10% germinated lentil flour; TU1 – 80% fermented provitamin A biofortified maize flour: 20% germinated lentil flour; 7QZ – 70% fermented provitamin A biofortified maize flour: 30% germinated lentil flour.

Table 3. Functional properties of complementary diet from provitamin A biofortified maize and germinated lentil seeds

Sample	Foaming capacity (%)	Foaming stability (%)	Water absorption capacity (ml/g)	Oil absorption capacity (ml/g)	Swelling capacity (%)	Bulk density (g/ml)	Dispersability (%)
AM4	8.19±0.10^{d}	1.64±0.10^{c}	1.67±0.05^{b}	2.10±0.01^{a}	59.52±0.02^{b}	0.72±0.02^{c}	29.76±0.02^{b}
L9G	11.48±0.02^{c}	1.64±0.01^{c}	1.66±0.05^{b}	2.01±0.10^{ab}	39.92±0.02^{c}	0.71±0.01^{c}	19.84±0.02^{c}
TU1	16.39±0.01^{b}	3.27±0.01^{b}	1.71±0.01^{b}	1.90±0.01^{bc}	49.61±0.02^{c}	0.82±0.02^{b}	19.82±0.02^{c}
7QZ	19.67±0.01^{a}	6.56±0.01^{a}	1.91±0.01^{a}	1.80±0.10^{c}	69.42±0.02^{a}	0.92±0.02^{a}	19.60±0.01^{a}

Values in column with the same superscript are not significantly different ($p \leq 0.05$). Means ± standard deviations of triplicate values. AM4: 100% Fermented provitamin A biofortified (FPVAB) maize flour; L9G – 90% fermented provitamin A biofortified maize flour: 10% germinated lentil flour; TU1 – 80% fermented provitamin A biofortified maize flour: 20% germinated lentil flour; 7QZ – 70% fermented provitamin A biofortified maize flour: 30% germinated lentil flour.

Functional properties of a complementary diet from provitamin A biofortified maize and germinated lentil seeds

Table 3 shows the functional properties of a complementary diet from provitamin A biofortified maize and germinated lentil seed. The foaming capacity ranged from 8.19 to 19.67 %. It was observed that as lentil seed increased foaming capacity increased. This agreed with the report of Fasuan et al. (2017) for complementary food from cereal, oil seed and animal polypeptide. Low values of foaming capacity indicated soluble proteins and low gas/volume ratio. The foaming stability ranged from 1.64 to 6.56 %. The same trend was observed in foaming stability: as germinated lentils increased, foaming stability increased too. There was a significant difference except for the samples AM4 and L9G, where no significant difference was observed probably because little or no quantity of germinated lentil seed was added. The water absorption capacity ranged from 1.66 to 1.91 ml/g. It was revealed that as the lentils increased, the water absorption capacity (WAC) increased. Water absorption capacity is an index of the maximum amount of water that a food product would absorb and retain (Marero et al., 1988). It was reported by Afam-Anene and Ahiarakwem (2014) that high water absorption capacity is disadvantageous in a complementary diet because it may limit the absorption of nutrients. The low WAC is desirable in order to make the gruel thinner with high caloric density per unit volume. The oil absorption capacity ranged from 1.80 to 2.10 ml/g. The obtained values reduced as the lentils increased in the samples. Oil absorption capacity is important as oil acts as a flavour retainer and gives soft texture to food by improving the mouth-feel (Aremu et al., 2006; Ubbor and Akobundu, 2009). The swelling capacity ranged from 39.92 to 69.42 %. It was revealed that as the lentil flour increased, the swelling capacity increased too. The lower swelling capacity is an advantage in complementary foods because it increases the nutrient density of the food that will enable the infants to consume more to meet up with the nutritional requirement (Afam-Anene and Ahiarakwem, 2014).

The bulk density ranged from 0.71 to 0.92 g/ml, with a significant difference, except for the samples AM4 and L9G, which are not significantly different and have the lowest bulk densities. It was observed that all the samples had high bulk density and the addition of the germinated lentil flour increased the bulk density. This was in accordance with the report of Tufa et al. (2016) for complementary foods from fermented cereals and soybean which had high bulk density. However, low bulk density food is desired where packaging is a serious problem (Desikarchar, 1980). Nnam (2000) reported that low bulk density has nutritional and economic significance as more of the products can be eaten resulting in high energy and nutritional density. The dispersibility ranged from 19.60 to 29.76 %. There was no significant difference in the values obtained for the samples L9G and NR8, while sample AM4 was significantly different from the sample 7QZ. The dispersibility index was low for all the diets; a similar case was reported in ogi supplemented with 30% soy tempe flour (Egounlety and Syarief, 1992). Also, this did not agree with the report of Sodipo and Fashakin (2011) that obtained a range of 41 – 73 %. The viscosities of the complementary diet from provitamin A biofortified maize and germinated lentils are shown in Fig. 1. It was observed that sample AM4 had the highest values for 90 – 30 °C, while the TU1 had lowest value except for 50 and 60 °C. It was revealed that as addition of germinated lentil increased, viscosity decreased. A low viscosity is nutritionally beneficial to the feeding of infants. According to Ikujenlola and Fashakin (2005), starch saccarification or dextrinification caused by the activities of amylase that developed during germination process gives reduction in the paste viscosity of the complementary diet prepared from germinated flour. Findings had showed that germination reduced viscosity of a complementary diet (Marero et al., 1988; Sajilata et al., 2002; Sodipo and Fashakin, 2011).

Mineral composition of the complementary diets from fermented provitamin A biofortified maize and germinated lentil seeds

The mineral composition of the complementary diets from fermented provitamin A biofortified maize and germinated lentils is presented in Table 4. Mineral elements present in food are generally utilized to reduce the occurrence of micronutrient malnutrition. Children develop birth defects and inability to learn properly, among other long-term disabilities when minerals are in an inadequate supply (Wierdsma et al., 2013). The sodium contents ranged from 13.50 to 24.40 mg/100g. It was observed that sodium reduced significantly as the added germinated lentils increased. This was shown in the values obtained reduced from 23.90 to 21.80. Also, it was revealed that fermentation increased the sodium content in W2F (unfermented provitamin A biofortified maize flour), which is 21.60 mg/100g compared to that of the 100% fermented provitamin A biofortified maize (24.40 mg/100 g). The values obtained were lowered than the recommended daily allowances (29.6 mg/100 g) for infants. The potassium content ranged from 177.5 mg/100 g to 1650.2 mg/100 g. There was a significant increase in potassium as the level of the germinated lentil flour increased. This is in accordance with the report of Desikachar (1980) that certain minerals are known to increase during germination. It was also increased in the fermented provitamin A biofortified

maize compared to the unfermented. The values obtained do not agree with the recommended values for infant formula (500 mg/100 g) (FAO/WHO, 1991). Potassium is required for proper functioning of cells, tissue and organs in the body. It is also crucial to heart functioning and plays a key role in skeletal and smooth muscle contraction making it important for a normal digestive and muscular function (Whitney et al., 1990).
The calcium content ranged from 208.38 to 368.63 mg/100 g. The results obtained were lowered than the recommended value of 516 mg/100 g (WHO/FAO, 2004). There was a significant difference in the reduction of the calcium content of the samples of the fermented and germinated blends compared to the unfermented provitamin A biofortified maize. Calcium is required by the growing children for strong bones and teeth, development of muscles and nerves, blood clotting and for the immune defense (Whitney et al., 1990). The iron contents ranged from 4.6 to 23.10 mg/100 g. It was only the unfermented provitamin A biofortified maize that met up with the standard, while the other samples did not meet up with recommended value of 16 mg/100 g. Iron is an essential micronutrient for the synthesis of haemoglobin (an oxygen carrier in the red blood cells), myoglobin (used for muscle contraction) and enzymes/coenzymes (used in various metabolic path-ways) (Whitney et al., 1990).
The low level of mineral composition of these complementary diets may be due to the fact that they are plant-based, which is also reported by Ikujenlola (2016).

Carotenoid content of a complementary diet from provitamin A biofortified maize and germinated lentil seeds

The results obtained for carotenoid are shown in Fig. 2. The values of the carotenoid content ranged from 0.80 to 1.27 mg/100 g. There was a significant difference in all the samples. W2F (control) had the highest value which may be because it was not fermented, while TU1 had the highest value. It was observed that fermentation reduced the amount of the carotenoid content, as the lentil flour increased carotenoid reduced. This agreed with the report of Li et al. (2007) that observed loss of provitamin A carotenoid in high β carotene maize.

Table 4. Mineral composition of complementary diets from fermented provitamin A biofortified maize and germinated lentils

Sample	Sodium (mg/100 g)	Potassium (mg/100 g)	Calcium (mg/100 g)	Iron (mg/100 g)
AM4	24.40±0.00	214.10±0.01	230.88±0.00	7.70±0.00
L9G	23.90±0.00	878.10±0.01	208.38±0.58	6.90±0.00
TU1	22.50±0.00	913.10±0.01	248.80±0.00	6.60±0.00
7QZ	21.80±0.00	1050.20±0.01	279.38±0.00	6.50±0.00
W2F	21.60±0.00	177.50±0.00	383.63±0.00	23.10±0.00
WHO/FAO recommended value	29.60	500.00	516.00	16.00

Values in column with the same superscript are not significantly different ($p \leq 0.05$). Means ± standard deviations of triplicate values. AM4: 100% Fermented provitamin A biofortified maize flour; L9G – 90% fermented provitamin A biofortified maize flour: 10% germinated lentil flour; TU1 – 80% fermented provitamin A biofortified maize flour: 20% germinated lentil flour; 7QZ – 70% fermented provitamin A biofortified maize flour: 30% germinated lentil flour; W2F: unfermented provitamin A biofortified maize flour.

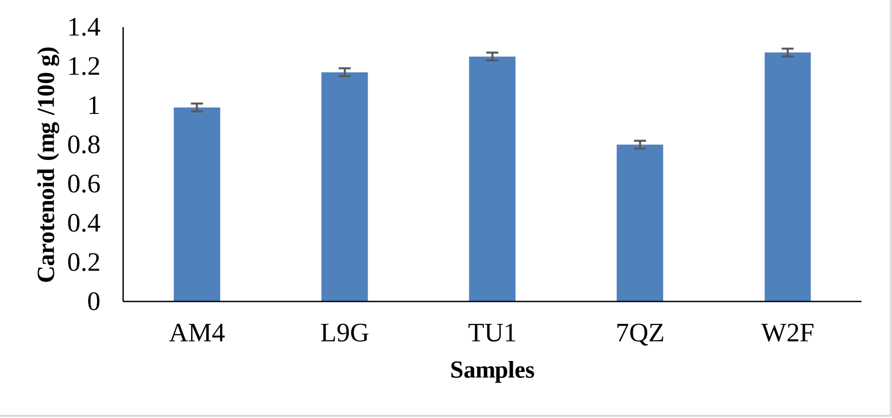

Fig. 2. Carotenoid content of complementary diets from provitamin A biofortified maize and germinated lentils. AM4: 100% Fermented provitamin A biofortified (FPVAB) maize flour; L9G – 90% fermented provitamin A biofortified maize flour: 10% germinated lentil flour; TU1 – 80% fermented provitamin A biofortified maize flour: 20% germinated lentil flour; 7QZ – 70% fermented provitamin A biofortified maize flour: 30% germinated lentil flour; W2F – Unfermented provitamin A biofortified maize flour.

Anti-nutritional factor of the complementary diet from provitamin A biofortified maize and germinated lentil seeds

The anti-nutritional factor of the complementary diet from provitamin A biofortified maize and germinated lentils are presented in Table 5. The phytate content ranged from 0.09 to 0.21 mg/100 g. The phytate content was high in control (unfermented provitamin A biofortified maize), but was reduced in other samples. It was observed that as lentil increased, the phytate content reduced. This may be due to the presence of phytate in the provitamin A biofortified maize. Trypsin inhibitor values ranged from 0.43 to 0.66 mg/100 g. There was a significant difference in all the samples. As the addition of lentil seed reduced, the trypsin inhibitor increased. The oxalate contents ranged from 0.04 to 0.10 mg/100 g. It was observed that the anti-nutritional content, particularly the oxalate and phytate of the samples containing fermented and germinated seeds was significantly lowered than that of the unfermented provitamin A biofortified maize, which served as control. This was in accordance with Ijarotimi and Keshinro (2012) that reported the decrease in the anti-nutrient composition of African locust beans that were fermented and germinated as compared to the raw sample.

Amino acid profile of a complementary diet from provitamin A biofortified maize and germinated lentil seeds

The amino acid profile of the complementary diet from provitamin A biofortified maize and germinated lentils id presented in Table 6 with thecorresponding FAO/WHO (1991) recommended daily allowance (RDAs). It was observed that as the germinated lentil increased, the essential and non-essential amino acids values increased. The most abundant essential amino acid was leucine, while glutamic acid was the most abundant non-essential amino acid. It was reported that high leucine might be a factor contributing to the development of pellagra as observed in maize (Aremu et al., 2006; FAO, 1995). Therefore, leucine/isoleucine was considered to be more essential. The obtained values were low within the range of 2.31 – 2.61. The values obtained for the essential amino acids (histidine, leucine, isoleucine, phenylalanine, valine and threonine) met up with the acceptable standard of the recommended daily allowance, except for methionine, tryptophan and lysine. However, the control (100% fermented provitamin A biofortified maize) had low values when compared to the acceptable standard. It was revealed from predicted nutritional qualities that the percentage of the total essential amino acid (TEAA) to total non-essential amino acid (TNEAA) ranged from 0.71 to 0.81. The percentage ratio of TEAA to total amino acid (TAA) in the samples ranged from 41.60 to 44.78, while that of TNEAA to TAA ranged from 55.21 to 58.40. All the samples had high values for proteins in diets of infants, 26% for children and 11% for adults as reported by FAO/WHO (1991). The quantity and quality of protein is an important consideration in child nutrition as they are both required for optimal growth and development. Protein quality is a function of the amino acids present. Amino acid profile is essential for determining the nutritive value of a diet. A protein food strength or weakness is based on the quality and quantity of its essential amino acid profile for healthy growth effects (Solomon and Owolawashe, 2006).

Sensory evaluation of the complementary diet from provitamin A biofortified maize and germinated lentil seeds

The sensory evaluation of complementary diets from provitamin A biofortified maize and germinated lentil seeds and commercial weaning food (control) is presented in Table 7. The appearance, aroma, taste, mouthfeel and overall acceptability values obtained ranged from 6.60 to 7.20, 6.50 to 7.50, 6.60 to 7.43, 6.40 to 6.97 and 6.50 to 7.70 respectively. There was no significant difference in the values obtained for appearance and mouthfeel. But it was observed that sample NR8 (control) was the most preferred for aroma, taste and overall acceptability, while sample 7QZ was the least preferred, maybe because it contained more of lentils. It was reported by Muhimbula et al. (2011) that in addition to energy density, sensory qualities of a complementary food formulation were of highest importance regarding food preferences for infants and young children.

Table 5. Anti-nutritional factor of the complementary diet from provitamin A biofortified maize and germinated lentils

Sample	Phytate (mg/100 g)	Trypsin Inhibitor (mg/100 g)	Oxalate (mg/100 g)
AM4	0.11 ± 0.02^{d}	0.43 ± 0.02^{d}	0.07 ± 0.02^{d}
L9G	0.15 ± 0.02^{b}	0.66 ± 0.02^{a}	0.04 ± 0.02^{a}
TU1	0.12 ± 0.02^{c}	0.55 ± 0.02^{b}	0.05 ± 0.02^{c}
7QZ	0.09 ± 0.02^{e}	0.47 ± 0.02^{c}	0.06 ± 0.02^{b}
W2F	0.21 ± 0.02^{a}	0.46 ± 0.02^{cd}	0.10 ± 0.02^{e}

Values in column with the same superscript are not significantly different ($p \leq 0.05$). Means ± standard deviations of triplicate values. AM4: 100% Fermented provitamin A biofortified (FPVAB) maize flour; L9G – 90% fermented provitamin A biofortified maize flour: 10% germinated lentil flour; TU1 – 80% fermented provitamin A biofortified maize flour: 20% germinated lentil flour; 7QZ – 70% fermented provitamin A biofortified maize flour: 30% germinated lentil flour; W2F – Unfermented provitamin A biofortified maize flour.

Table 6. Amino acid profiles of the complementary diet from provitamin A biofortified maize and germinated lentils

Samples	7QZ	TU1	L9G	AM4	RDA
Essential Amino Acids					
Leucine	8.23	7.76	6.83	5.31	6.60
Lysine	4.56	4.03	3.87	3.13	5.80
Isoleucine	3.34	3.01	2.95	2.03	2.80
Phenylalanine	4.43	4.08	3.81	3.01	2.80
Trytophan	0.79	0.68	0.63	0.42	1.40
Valine	3.80	3.51	2.98	2.45	3.50
Methionine	1.23	1.01	0.8	0.64	2.20
Histidine	2.81	2.56	2.17	1.72	1.90
Threonine	3.33	3.38	2.77	3.00	3.40
TEAA	32.62	30.02	26.81	21.71	
Non-Essential Amino Acids					
Proline	4.47	3.25	2.84	2.44	–
Arginine	5.16	4.64	3.96	3.01	2.00
Tyrosine	3.44	3.1	2.58	2.24	2.80
Alanine	4.32	3.56	3.11	3.18	–
Glutamic acid	13.32	10.6	9.31	7.27	–
Glycine	3.28	3.04	2.66	2.71	–
Cystine	1.09	0.91	0.73	0.48	2.00
Serine	3.4	2.86	2.54	1.89	–
Aspartic acid	7.32	7.38	5.33	5.02	–
TNEAA	45.8	39.34	33.06	28.24	
TAA	78.42	69.36	59.87	49.95	
TEAA / TNEAA	0.71	0.76	0.81	0.77	
TEAA / TAA (%)	41.60	43.28	44.78	43.46	
TNEAA / TAA (%)	58.40	56.71	55.21	56.53	
Leucine / Isoleucine	2.46	2.58	2.31	2.61	
TSAA (Methionine + Cystine)	2.32	1.92	1.53	1.12	
ArESAA (Phenylalanine + Tyrosine)	7.87	7.18	6.39	5.25	

AM4: 100% Fermented Provitamin A biofortified (FPVAB) maize flour; L9G: 90%FPVAB maize:10%germinated lentils; TU1: 80%FPVAB maize:20%germinated lentils; 7QZ: 70%FPVAB maize:30% germinated lentils; TEAA: Total Essential Amino Acids in the samples. TNEAA: Total Non-essential Amino Acids; TAA: Total Amino Acids. RDA: Recommended Daily Allowance (FAO/WHO, 1991)

Table 7. Sensory evaluation of complementary diets from provitamin A biofortified maize and germinated lentils

Sample	Appearance	Aroma	Taste	Mouth-feel	Overall acceptability
AM4	7.17 ± 1.58^{a}	6.83 ± 1.23^{ab}	7.13 ± 1.17^{ab}	6.50 ± 1.36^{a}	7.23 ± 1.10^{ab}
L9G	7.13 ± 1.57^{a}	6.77 ± 1.46^{ab}	7.30 ± 1.02^{ab}	6.67 ± 1.63^{a}	7.13 ± 1.61^{ab}
TU1	7.20 ± 1.21^{a}	6.80 ± 1.35^{ab}	7.20 ± 1.19^{ab}	6.57 ± 1.92^{a}	7.37 ± 1.22^{ab}
7QZ	6.60 ± 1.40^{a}	6.50 ± 1.59^{b}	6.60 ± 2.03^{b}	6.40 ± 1.79^{a}	6.50 ± 1.98^{b}
NR8 (Control)	7.13 ± 1.83^{a}	7.50 ± 1.55^{a}	7.43 ± 1.50^{a}	6.97 ± 1.75^{a}	7.70 ± 1.76^{a}

Values in column with the same superscript are not significantly different ($p \leq 0.05$). Means ± standard deviations of triplicate values.
AM4: 100% Fermented provitamin A biofortified (FPVAB) maize flour. L9G – 90% fermented provitamin A biofortified maize flour: 10% germinated lentil flour; TU1 – 80% fermented provitamin A biofortified maize flour: 20% germinated lentil flour; 7QZ – 70% fermented provitamin A biofortified maize flour: 30% germinated lentil flour; NR8: Commercial infant formula (control).

Conclusion

This study concluded that complementary diets of fermented provitamin A biofortified maize and germinated lentil had high protein and carbohydrate contents, as well as high energy values that met up with the recommended standards. The foaming capacity, foaming stability, water and oil absorption capacity, dispersibility and viscosity of the formulated complementary diet were low, while swelling capacity and bulk density increased with an increase in the amount of lentil seeds. It was observed that all the samples had low mineral contents of sodium, calcium and iron, high potassium when compared to WHO/FAO recommended value, therefore, fortification will be needed. The carotenoid contents, phytate and oxalate of the complementary diets were reduced, while samples TU1 and 7QZ had high trypsin inhibitors. Also, it was revealed that majority of the samples met up with the recommended standards for essential and non-essential amino acids except for tryptophan, methionine, threonine and cystine. The sample TU1 (80:20%) was most accepted, apart from the control (commercial maize-soya weaning food – Nestle-Cerelac). Therefore, this may serve as a mean to prevent and ameliorate protein-energy malnutrition in infants.

References

Adeniyi, M. A., Fashakin, J. B., Samson I. I. (2014): Determination of mineral contents, proximate composition and functional properties of complementary diets prepared from maize, soybean and pigeon pea. *American Journal of Nutrition and Food Science* 1 (3), 53–56. https://doi.org/10.12966/ajnfs.07.01.2014

Afam-Anene, O. C. Ahiarakwem J. H. (2014): Nutritional Quality, Functional and Sensory Evaluations of Complimentary Food made from Cereals, Legumes, Oil seeds and Vegetable. Proceedings, 43rd Annual General Meeting and Scientific Conference, 3rd – 7th.

Alozie, Y., Akpanabiatu, M. I., Eyong, E. U., Umoh, I. B. Alozie, G. (2009): Amino acid composition of Dioscorea dumetorum varieties. *Pakistan Journal of Nutrition* 8, 103-105.

Association of Official Analytical Chemists. (AOAC) (1998): Official Methods of Analysis. 16th edition, Association of Official Analytical Chemists International, Arlington, VA.

Association of Official Analytical Chemists (AOAC) (2005): Official Method of Analysis. 18th Edition, Association of Official Analytical Chemists International, Washington; D. C.

Aremu, M. O., Olonisakin, A., Atolaye, B. O. Ogbu, C. F. (2006): Some nutritional and functional studies of *Prosopis africana*. *Electron Journal of Environmental Agriculture and Food Chemistry* 5, 1640-1648.

Beaton, G. H., Martorell, R., Aronson, K. J., Edmonston, B., McCabe, G., Ross, A. C. Harvey, B. (1993): Vitamin A deficiency and attributable mortality among under-5-year-olds. Effectiveness of vitamin A supplementation in the control of young child morbidity and mortality in developing countries. Nutrition Policy Discussion Paper 13. Administrative Committee on Coordination—Subcommittee on Nutrition, WHO, Geneva.

Benitez, L. V. (1989): Amino acid and fatty acid profiles in aquaculture nutrition studies, 23 – 35. In: De Silva, S. S. (editor). Fish Nutrition Research in Asia. Proceedings of the Third Asian Fish Nutrition Network Meeting. Asian Fisheries Society, Manila Philippines. *Asian Fish Society Special Publication* 4, 166.

Bhatty, R. S. (1988): Composition and Quality of Lentil (*Lens-culinaris Medik*) – A review. *Food Science and Technology International* 21, 144-160. https://doi.org/10.1016/S0315-5463(88)70770-1

Crosbie G. B. (1991): The relationship between swelling properties, 510 paste viscosity and boiled noodle quality in wheat flours. *Journal of Cereal Science* 13, 145-150. https://doi.org/10.1016/S0733-5210(09)80031-3

Day, Jr. R.A., Underwood, E.L (1986): Quantitative analysis 5th edition, Prentice- Hall Publication London: 701

Desikachar, H. S. R. (1980): Development of weaning foods with high caloric density and low hot-paste viscosity using traditional technologies. *Food and Nutrition Bulletin* 2 (4), 21-23.

Egounlety, M., Syarief, R. (1992): Study on the supplementation of Ogi with Tempe. *Nigerian Food Journal* 10, 92-102.

Elkhalifa, A.E.O., Schiffler, B., Bernhardt, R (2005): Effect of fermentation on the functional properties of sorghum flour. *Food Chemistry* 92 (1), 1-5. https://doi.org/ 10.1016/j.foodchem.2004.05.058

Fasasi, O. S., Eleyinmi, A. F., Fasasi, A. R., Karim, O. R. (2004): Chemical properties of raw and processed breadfruit (*Treculia africana*) seed flours. *Food Agriculture and Environment* 2, 65-68.

Fasuan, T. O., Fawale, S. O., Enwerem, D. E., Uche, N., Ayodele, E. A. (2017): Physicochemical, Functional and Economic Analysis of a Complementary Food from Cereal, Oil seed and Animal Polypeptide. *International Food Research Journal* 25 (1), 275-283.

Fikiru, O., Bultosa, G., Forsido, S. F., Temesgen, M. (2016): Nutritional quality and sensory acceptability of complementary food blended from maize (*Zea mays*), roasted pea (*Pisum sativum*), and malted barley (*Hordium vulgare*). *Food Science and Nutrition* 5 (2), 173-181.

Food and Agricultural Organization of the United Nations (FAO). (1995): Energy and Protein Requirements. Report of a joint FAO/WHO. Expert consultation. WHO Technical Report Series Number, 74, 86-98.

Food and Agricultural Organization of the United Nations and World Health Organization (FAO/WHO). (1985): Report of a joint protein requirement. World Health Organization. Technical Report Series 724, Geneva.

Food and Agricultural Organization of the United Nations and World Health Organization. (FAO/WHO). (1991): Protein quality evaluation. Report of Joint FAO/WHO Experts Consultation. FAO, Food and Nutrition Paper, 51. Rome, Italy: 1-66.

Humphrey, J. H., West, K. P., Jr., Sommer, A. (1992): Vitamin A deficiency and attributable mortality among under-5-year-olds. *Bulletin of W.H.O.* 70, 225-232.

Ibeanu, V., Okeke, E. G. (2001): Development and acceptability test of amylase-rich flour (ARF) enriched complementary foods. *Nigerian Journal of Nutritional Science* 22 (1), 13-19.

Ijarotimi O. S., Keshinro O. O. (2012): Comparison between the amino acid, fatty acid, mineral and nutritional quality of raw, germinated and fermented African locust bean (*Parkia biglobosa*) flour. *Acta scientiarum polonorum. Technologia alimentaria* 11 (2), 151-165.

Ikegwu, O. J., Nwobasi, V. N., Odoh, M. O., Oledinma, N. U. (2009): Evaluation of the Pasting and Some Functional Properties of Starch Isolated from Some Improved Cassava Varieties in Nigeria. *African Journal of Biotechnology* 8, 2310-2315.

Ikujenlola, A. V., Fashakin, J. B. (2005): The Physicochemical Properties of a Complementary Diet Prepared from Vegetable Proteins. *Journal of Food Agriculture and Environment* 3 (3&4), 23-26.

Ikujenlola, A. V. (2016): Quality and in vivo assessment of precooked weaning food from quality protein maize, soybean and cashew nut flour blends. *Croatian Journal of Food Technology, Biotechnology and Nutrition* 11 (1&2), 49-57.

Jiang, Y. Z., Wang, T. (2005). Phytosterols in cereal by-products. *Journal of the American Oil Chemists' Society* 82, 439-444. https://doi.org/ 10.1007/s11746-005-1090-5

Kopsell, D. A., Armel, G. R., Mueller, T. C., Sams, C. C., Deyton, D. E., McElroy, J. S., Kopsell, D. E. (2009): Increase in nutritionally important sweet corn kernel carotenoids following mesotrione and atrazine applications. *Journal of Agriculture and Food Chemistry* 57, 6362-6368. https://doi.org/ 10.1021/jf9013313

Kulkarni, K. D., Kulkarni, D. N., Ingle, U. M. (1991): Sorghum malt-based weaning formulations preparation, functional properties, and nutritive value. *Food and Nutrition Bulletin* 13 (4), 322-327.

Latham, M.C. (1997): Human Nutrition in the Developing World. Food and Agriculture Organization (FAO), Rome, Italy. *Food and Nutrition Series* 2 (29).

Li, S., Tayie, F.A.K., Young, M.F., Rocheford, T., White, W.S (2007): Retention of provitamin A carotenoids in high β carotene maize (Zea mays) during traditional African household processing. Journal of Agriculture and *Food Chemistry* 55, 10744-10750. https://doi.org/ 10.1021/jf071815v

Lopez-Martinez, L. X., Oliart-Ros, R. M., Valerio-Alfaro, G., Lee, C. H., Parkin, K. L., Garcia, H. S. (2009): Antioxidant activity, phenolic compounds and anthocyanin contents of eighteen strains of Mexican maize, LWT. *Food Science and Technology* 42, 1187-1192. https://doi.org/ 10.1016/j.lwt.2008.10.010

Makkar, H.P.S., Goodchild, A.V (1996): Quantification of tannins: A Laboratory Manual. International centre for agricultural research in dry areas, Aleppo, Syria.

Marero, L.M., Payumo, E.M., Lirando, E.C., Larez, W.N., Gopez, M.D., Homa, S. (1988): Technology of weaning food formulation prepared from germinated cereals and legumes. *Journal of Food Science* 53, 1391-1398. https://doi.org/10.1111/j.1365-2621. 1988.tb09284.x

Muhimbula, H. S., Issa-Zacharia, A., Kinabo, J. (2011): Formulation and sensory evaluation of complementary foods from local, cheap and readily available cereals and legumes in Iringa, Tanzania. *African Journal of Food Science* 5 (1), 26-31.

Naranyana, K., Narasinga-Rao, M.S (1982): Functional properties of lupin seed proteins and protein concentrates. *Journal of Food Science* 47, 491-495

Ndagire, C. T., Muyonga, J. H., Manju, R., Nakimbugwe, D. (2015): Optimized formulation and processing protocol for a supplementary beanbased composite flour. *Food Science and Nutrition* 3 (6), 527-538. https://doi.org/ 10.1002/fsn3.244

Nkama, I., Gbenyi, D.I. (2001): The effect of malting of millet and sorghum on the residue phytate and poly-phenol in "Dakura", a Nigerian cereal/legume snack food. *Nigerian Journal of Tropical Agriculture* 3, 270-271.

Nnam, N. M. (2000): Evaluation of complementary foods based on maize, groundnut, pawpaw and mango flour Blends. *Nigerian Journal of Nutrition Science* 22&23, 8–18.

Nwanekezi, E.C., Ohagi, N.C., Afam-Anene, O.C (2001): Nutritional and organoleptic quality of infant food formulation from natural and solid-state fermented tubers (cassava, sprouted and unsprouted yam), soyabean flour blend. *Nigerian Food Science Journal* 19, 55-62

Okorie, S. U., Ekwe, C. C. (2017): The comparative analysis of sprouted legume and cereal based composite diet. *Journal of Applied Biotechnology and Bioengineering* 4 (2), 554-561.

Onofiok, O. N., Nnanyelugo, D. O. (1998): Nigerian weaning foods. *Food and Nutrition Bulletin* 2, 29-33.

Palmer, A. C., Siamusantu, W., Chileshe, K., Schulze, K. J., Barffour, M., Craft, N. E., Molobeka, N., Kalungwana, N., Arguello, M. A., Caswell, M. M., Klemm, R., West, K. P. (2016): Provitamin A bio-fortified maize increases serum β-carotene, but not retinol, in marginally nourished children: a cluster-randomized trial in rural Zambia. *The American Journal of Clinical Nutrition* 104 (1), 181-190. https://doi.org/ 10.3975/ajcn.116.132571

Pillay, K., Derera, J., Siwela, M., Veldman, F.J. (2011): Consumer acceptance of yellow Provitamin A- biofortified maize in KwaZulu-Natal. South Africa *Journal of Clinical Nutrition* 4 (4), 186-191. https://doi.org/ 10.1080/16070658.2011.11734386

Sajilata, G.,Singhal, R.S., Kulkani, P.R (2002): Weaning food: A review of the Indian experience. *Food and Nutrition Bulletin* 23 (2), 208-226.

Sodipo, M. A., Fashakin, J. B. (2011): Physico-chemical properties of a complementary diet prepared from germinated maize, cowpea and pigeon pea. *Journal of Food, Agriculture and Environment* 9(3 & 4), 23-25.

Solomon, M., Owolawashe, H. (2006): The Analyses of Amino Acid, Fatty Acid And Mineral In A Legume-Cereal Based Complementary Food Blend Used In Jos, Nigeria. *The Internet Journal of Nutritional Wellness* 4 (1), 3-7.

Tanumihardjo, S. A. (2008): Food-based approaches for ensuring adequate vitamin A nutrition. *Comprehensive Reviews in Food Science and Food Safety* 7, 373-381.

Thavarajah, D., Thavarajah, P., Sarker. A., Vandenberg, A. (2009): Lentils (Lens culinaris Medikus Subspecies culinaris): a whole food for increased iron and zinc intake. *Journal of Agriculture and Food Chemistry* 57 (12), 5413-5419. https://doi.org/ 10.1021/jf900786e

Thavarajah, D., Johnson, C., McGee, R., Thavarajah, P. (2015): Phenotyping nutritional and antinutritional traits. In: Kumar, J., and Pratap A. (editors). Phenomics in Crop Plants: Trends, Options and Limitations. Springer; New Delhi, India: 223-233.

Tufa, M. A., Weledesemayat, G. T., Mitiku, B. G. (2016): Development and Nutritional Assessment of Complementary Foods from Fermented Cereals and Soybean. HSOA *Journal of Food Science and Nutrition* 2 (2), 1-8. https://doi.org/ 10.24966/FSN-1076/100014

Ubbor, S. C., Akobundu, E. N. T. (2009): Quality Characteristics of Cookies from Composite Flours of watermelon seed, Cassava and Wheat. *Pakistan Journal of Nutrition* 8, 1097-1102.

West, K. P. (2002): Extent of vitamin A deficiency among preschool children and women of reproductive age. *Journal of Nutrition* 132, 2857S-2866S.

Wierdsma, N. J., Bokhorst, M. A., Berkenpas, M., Mulder, C. J., Bodegraven, A. A. (2013): Vitamin and mineral deficiencies are highly prevalent in newly diagnosed celiac disease. *Nutrient* 5, 3975-3992.

Whitney, E. N., Hamilton E. M. N., Rolfes, S. R. (1990): Understanding Nutrition. 5th edition, West Publishing Company, St. Paul, Minnesota, J3 – J4.

World Health Organization (WHO) / Food and Agricultural Organization of the United Nations (FAO). (2004): Vitamin and mineral requirements in human nutrition. Second edition. Geneva/Rome: WHO/FAO.