Lactating mothers’ perceptions and sensory acceptability of a Provitamin A carotenoid-iron rich composite dish prepared from iron biofortified common bean and orange-fleshed sweet potato in rural western Uganda

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Research Article

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Abstract

Background

Lactating mothers are at higher risk for developing the two leading micronutrient deficiencies of vitamin A deficiency (VAD) and iron deficiency (ID) because of the physiological demands of vitamin A and iron that increase during breastfeeding. However, Uganda's lactating mothers are more vulnerable to VAD and ID because they consume plant-based conventional non-biofortified foods such as white-fleshed sweet potato (WFSP) and non-iron biofortified common bean (NIBCB) that are low in provitamin A (PVA) and iron, respectively. A PVA carotenoid-iron rich dish was prepared from a combination of PVA biofortified sweet potato, orange-fleshed sweet potato (OFSP) and iron biofortified common bean (IBCB). Therefore, this study evaluated the perceptions and sensory acceptability of OFSP + IBCB (test food) against WFSP + NIBCB (control food) among lactating mothers in rural Uganda.

Methods

This crossover acceptability study randomly selected ninety-four lactating mothers to participate in the study. The sensory attributes (taste, color, aroma, texture, and general acceptability) of OFSP + IBCB and WFSP + NIBCB were rated using a five-point facial hedonic scale (1 = dislike very much, 2 = dislike, 3 = neutral, 4 = like 5 = like very much). Focus group discussions (FGDs) were conducted to assess the perceptions of lactating mothers about their future consumption of OFSP + IBCB. The chi-square test was used to detect the proportion difference for each sensory attribute between OFSP + IBCB and WFSP + NIBCB, whilst FGD data were analyzed by thematic analysis. An attribute was considered acceptable if the participant scored from like to like very much (4 to 5) on the 5-point facial hedonic scale.

Results

The texture of OFSP + IBCB was significantly not accepted compared to that of WFSP + NIBCB (P < 0.05). However, there was no significant difference in lactating mothers' acceptability for all the other attributes of taste, color, aroma, and general acceptability. Lactating mothers had positive perceptions of the taste, aroma, and color of the OFSP + IBCB and negative perceptions about the soft texture of OFSP. The lactating mothers were keen to know where to access, the market price, and the preparation costs of OFSP + IBCB.

Conclusion

Based on taste, color, aroma, and general acceptability, OFSP + IBCB and WFSP + NIBCB were equally acceptable among lactating mothers. The lactating mothers had positive perceptions of using OFSP + IBCB provided they were accessible, affordable, and feasible to prepare them.
Background

Dietary iron deficiency (ID) and vitamin A deficiency (VAD) are the two leading micronutrient deficiencies of public health nutrition importance that negatively impact women of reproductive age (WRA) residing in low and middle-income countries (LMICs) of Africa and Asia [1–3]. However, the highest-burden is among pregnant and lactating women because of the increased physiological demands for iron and vitamin A which increase due to either fetal demands during pregnancy or breastfeeding during lactation [4,5]. If neglected, vitamin A requirements that occur during lactation are associated with clinical VAD characterized by night blindness and bitot’s spot among lactating mothers [6]. The increased iron demands among WRA coupled with the intake of low-iron foods are associated with ID anemia, the leading cause of maternal anemia in LMICs [7]. Moreover, the progress on anemia in WRA (15–49 years) is insufficient to meet the World Health Assembly's global nutrition target to halve anemia prevalence by 2030 in LMICs including Uganda [8].

The Recommended Dietary Allowance (RDA) is the average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all healthy individuals in a particular life stage and sex group. It is worth noting that the RDA for vitamin A among lactating mothers is higher at 885-1300µgRAE/day compared to pregnant women at 700µgRAE/day [5,9]. Moreover, the RDA for iron needed by lactating mothers is high at 10-30mg/day compared to 8mg/day for adult males [10,11]. To contribute towards achieving the RDA for iron among lactating mothers, iron supplementation programs are recommended by the World Health Organization (WHO) during the period of postpartum, beginning just after neonate delivery to the first six weeks after delivery [10]. In contrast, the WHO doesn't recommend vitamin A supplementation during postpartum because it has neither health benefits to the mother nor the infant [12]. However, it recommends that the lactating mother should consume a diversified diet including vitamin A-rich foods [12]. It is worth noting that vitamin A and iron supplementations during postpartum have the potential to improve the breast milk content of vitamin A and iron, respectively [13,14]. This is important because it improves the vitamin A intake of the breastfeeding child, and therefore may improve the vitamin A and iron status of the breastfeeding infant. However, postpartum vitamin A and iron supplementations are not sustainable because are done for only the first six weeks after delivery, yet lactation should go up to two years and beyond as recommended by the WHO [15]. Therefore, a continued intake of either vitamin A and iron-fortified foods or vitamin A and iron animal source foods such as meat and liver would be necessary to improve the vitamin A and iron status of lactating mothers and their breast milk [16]. However, vitamin A and iron-fortified foods are either expensive or not available on the market to be accessed by poor mothers who reside in LMICs and rural settings.

A high proportion of lactating mothers residing in rural Uganda are at an increased risk of developing VAD and iron deficiency anemia because they habitually consume staple plant-source foods (PSFs) that are low in PVA carotenoids and iron [17]. The staple PSF are usually either tubers such as conventional non-PVA biofortified sweet potato (*Ipomoea batatas*) such as white-fleshed sweet potato (WFSP), or low-iron conventional non-iron biofortified common bean (NIBCB) such as *Nambale*. Plant biofortification is a nutrition-sensitive strategy that increases the concentration of target nutrients, particularly micronutrients,
such as iron, and vitamin A in the edible portions of staple food crops through conventional breeding, fertilizer application, or bioengineering (recombinant DNA technology) to improve the nutritional status of target consumers [18]. Compared to other nutrition-specific strategies such as industrial fortification and supplementation traditionally used to combat VAD and ID, biofortification is relatively cost-effective because once biofortified seeds are released, the rural poor from LMICs can plant them season after season for sustained consumption [19,20].

To contribute towards improved vitamin A and iron intake among vulnerable groups to VAD and ID such as lactating mothers, the government of Uganda through HarvestPlus introduced PVA biofortification and iron biofortification programs for its staple foods such as sweet potato (*Ipomoea batatas*) and common bean (*Phaseolus vulgaris*), respectively [21–23]. Therefore, the PVA biofortified sweet potato, orange-fleshed sweet potato (OFSP), and iron biofortified common bean (IBCB) were introduced in Uganda. Substituting conventional non-iron and provitamin A biofortified foods with iron and provitamin A biofortified foods is increasingly seen as a potential strategy for combating ID and VAD in LMICs of Africa [24–26]. It is worth noting that understanding the acceptability of these biofortified foods is a prerequisite for future consumer utilization of such biofortified foods [27,28].

In Uganda, a dish prepared from a combination of WFSP and NIBCB is commonly consumed among WRA including lactating mothers [29]. However, a combination of WFSP and NIBCB is low in PVA carotenoids and iron, respectively [30]. When such a combination is habitually eaten, it has the potential to increase the risk of VAD and ID among Uganda consumers [31,32]. To contribute towards improving PVA carotenoid and iron intake among lactating mothers in rural Uganda, a PVA carotenoid-iron rich innovative dish was prepared from a combination of OFSP and IBCB released in Uganda. This is plausible because the former is rich in PVA carotenoids [33], and the latter is rich in iron [34]. Therefore, this study evaluated the perceptions and sensory acceptability of a PVA carotenoid-iron rich OFSP+IBCB (test composite foods) against the low PVA carotenoid-iron WFSP+ NIBCB (control composite foods) among lactating mothers in rural Uganda. Findings generated from this study inform whether a dish of OFSP+IBCB rich in PVA carotenoids and iron has the potential to replace the conventional dish WFSP+NIBCB which is low in PVA carotenoids and iron among Uganda’s lactating mothers.

**Methods**

*Study setting and design*

This experimental cross-over sensory acceptability study was conducted in Bwera general Hospital, located in Kasese district, western Uganda. The study was conducted in Kasese district because based on the most recent Uganda demographic and health survey, Kasese is among the districts located in Tooro region (western Uganda) with the highest prevalence (over 50%) of anemia among WRA [35]. Bwera Hospital was specifically chosen because it is a district referral hospital that receives over 500 lactating mothers in a month for postnatal services from all over the district.

*Study participants and sample size determination*
The lactating mothers rated the taste, texture, aroma, color, and overall acceptability of both the taste food and control samples using a five-point facial hedonic scale (1 = dislike very much = 1, dislike = 2, neutral, 3, like = 4 and like very much = 5). A participant was considered to accept the composite food if she scored 4 and above (like to like very much). Therefore, the sample size was determined to test the hypothesis that the mean score of the sensory attribute would be 4 and above. The sample size was calculated by use of the statistical considerations for a cross-over study software available at http://hedwig.mgh.harvard.edu/sample_size/js/js_crossover_quant.html with the following parameters and assumptions. The probability is 80% that the study will detect a treatment difference at a two-sided 0.05 significance level if the true difference between the study foods is a sensory acceptability score of 0.02. This was based on the assumption that the within-participant standard deviation of the sensory acceptability variable is 0.02. To this end, a sample size of 65 lactating mothers for each study composite dish would therefore allow us to reject the null hypothesis with 80% power. Moreover, a minimum sample size of 60 participants is considered adequate for a valid sensory acceptability study [36].

**Sampling procedure, inclusion and exclusion criteria of study participants**

The lactating mothers were recruited by systematic sampling method. In systematic sampling, a number is assigned to every record, and then every nth record is selected from a list [37]. On average 30 lactating mothers come for postnatal services in Bwera general hospital every day. This study systematically recruited 10 of 30 lactating mothers per day in the postnatal clinic of Bwera Hospital between the 4th and 15th of August 2023. The following procedure was followed: Every morning, a list of all the first 30 lactating mothers to come for postnatal services was obtained. To this end, 30/10 = 3. Therefore, every third lactating mother was recruited. A number from 1 to 3 was chosen at random as a starting point. In this case, number 3 was chosen at random. Therefore, every 3rd lactating mother was recruited in the study. That is to say, lactating mothers number 3, 6, 9, 12, 15, 18, 21, 24, 27, and 30 were recruited every day until the calculated sample size was reached. A study participant was included in the study when she had a breastfeeding child. A lactating mother was excluded from the study if she had any form of illness. This exclusion criterion was considered because several illnesses may affect sensory variables such as smell and taste for mothers during the period of lactation [38].

**Sampling procedure, inclusion and exclusion criteria of study participants**

The lactating mothers were recruited by systematic sampling method. In systematic sampling, a number is assigned to every record, and then every nth record is selected from a list [37]. On average 30 lactating mothers come for postnatal services in Bwera general hospital every day. This study systematically recruited 10 of 30 lactating mothers per day in the postnatal clinic of Bwera Hospital between the 4th and 15th of August 2023. The following procedure was followed: Every morning, a list of all the first 30 lactating mothers to come for postnatal services was obtained. To this end, 30/10 = 3. Therefore, every third lactating mother was recruited. A number from 1 to 3 was chosen at random as a starting point. In this case, number 3 was chosen at random. Therefore, every 3rd lactating mother was recruited in the
study. That is to say, lactating mothers number 3, 6, 9, 12, 15, 18, 21, 24, 27, and 30 were recruited every day until the calculated sample size was reached. A mother was included in the study when she had a breastfeeding child. A lactating mother was excluded from the study if she had any form of illness. This is because several illnesses may affect sensory variables such as smell and taste during postpartum [38].

**Pilot study**

A pilot study is a preliminary step of the entire research protocol and is often a smaller-scale investigation that aids in the preparation and adjustment of the main study. The pilot study was conducted to test the feasibility of methods and procedures for the preparation of study foods, sensory evaluation, and focus group discussions (FGDs) for later use in the main study. The village health team members (community health workers) identified five peer mothers from the community who participated in the preparation and cooking of the study foods. The peer mothers advised on the common cooking methods used to prepare common beans and sweet potatoes at the household level. For example, they advised that common bean is soaked in water overnight (approximately 8 to 10 hours) before it is boiled and fried for consumption, whilst sweet potato is peeled and cooked by local steaming methods. Moreover, boiling common bean with prior soaking and steaming OFSP have demonstrated that they have a higher retention of iron and PVA carotenoids, respectively [39,40]. These cooking methods were adopted in the preparation of study composite dishes for sensory evaluation during the main study. The midwives identified 20 lactating mothers from the post-natal clinic of Bwera Hospital to participate in the sensory evaluation and FGD pilot study.

A total number of 20 lactating mothers participated sensory evaluation pilot study. A short while later, all the 20 lactating mothers who had participated in the sensory evaluation, participated in the pilot FGDs. Two FGDs were conducted during the pilot study and each focus group had 10 lactating mothers. The pilot study was conducted one week before the main study. This pilot study was conducted on a different day from the main study to prevent the pilot study participants from participating in the main study. The pilot study established that the majority (98%) of the lactating mothers who participated in the pilot study had low literacy levels (did not complete primary education). This was confirmed by records from the post-natal clinic. Knowing the literacy level of the potential study participants guided the main study to modify the sensory evaluation hedonic scale from a seven-point scale to a five-point scale. It is worth noting that longer hedonic scales, such as those with 7 or 9 rating scales, tend to confuse participants with lower literacy levels, while rating scales that are shorter than the five-point scale tend to cause end-point avoidance [41]. As the pilot study venue was too far away from the postnatal clinic, a closer alternative venue was identified for the main study. No changes were made to the FGD guide after the pilot study. The pilot study was also used to train research assistants. This helped the research assistants to get acquainted with the implementation of the sensory evaluation questionnaire and focus group discussion guide.

**Description of the control and test composite dishes used in the study**
Ingredients for the preparation of the study composite dishes

Composite foods are foods characterized by being multi-ingredient and include both ready-to-eat products and home-prepared dishes [42]. This study used home-based cooking methods commonly used to prepare common beans and sweet potatoes in Uganda. The control composite dish was WFSP served with NIBCB (WFSP+NIBCB). This combination was selected because it is a non-biofortified dish habitually consumed in Uganda and it is characterized by low PVA carotenoids and iron. The innovative test composite dish was OFSP served with IBCB (OFSP+IBCB). The test composite dish was selected because the former is biofortified with PVA carotenoids, whilst the latter is biofortified with iron. Figure 1 shows the ingredients used to prepare the control and test composite dishes for the acceptability study.

Preparation of test and control composite dishes

The village health team members (community health workers) identified five expert peer mothers from the local community and invited them to Bwera Hospital kitchen to participate in the preparation of the study composited dishes. Expert peer mothers were encouraged to prepare the composite dishes using the locally acceptable home-based methods used in the community to prepare common beans and sweet potatoes to be consumed by lactating mothers. The biofortified foods, OFSP (NKB 135) and IBCB (NARO bean 4c) were procured from the National Crops Resources Research Institute (NaCRRI), Namulonge, Uganda [43]. The commonly consumed WFSP (Ebiribwa) and NIBCB (Nambale) in the community were procured from the local market by expert peer mothers who prepared the composite dishes used in the study in the presence of the research assistants. The peer mothers soaked the NIBCB and IBCB separately overnight (approximately 8 to 10 hours) before cooking them by boiling. The mothers chose to boil common beans with prior soaking because they argued that soaking softens common beans to reduce cooking time and saves fuel as reported in the previous Ugandan study [39]. The IBCB and NIBCB were cooked separately using a local stove (Esigiri) until they were soft and ready for human consumption. The cooking time for NIBCB and IBCB was approximately 1.5 hours and 3.5 hours, respectively. Expert peer mothers prepared sweet potato by peeling, washing it followed by steaming it separately OFSP from WFSP. The local method of steaming involved putting 1 liter of tap water into the cooking pot, followed by banana stalks, then banana leaves, in which sweet potato was wrapped before being put onto the hot charcoal stove for steaming. The role of the banana stalk was to create an elevation and separation between the water in the cooking pot from the banana leaves, where the sweet potatoes were wrapped. To this end, when water in the pot boils, it releases steam that vaporizes through the banana stalk spaces to heat the banana leaves in which the sweet potatoes were wrapped. The cooking time for WFSP and OFSP was approximately 45 minutes and 35 minutes, respectively. The duration of boiling and steaming was sufficient to soften the plant tissue as assessed by the penetration of the tip of a knife without resistance [39].

Provitamin A carotenoids, vitamin A, and iron composition of cooked study foods

The PVA carotenoid composition of cooked sweet potato was analyzed by high-performance liquid chromatography as described in the HarvestPlus handbook for carotenoid analysis [44]. The vitamin A
composition was calculated by using the Institute of Medicine (2001) bioconversion rates of PVA carotenoids to vitamin A (retinol activity equivalents), i.e., 12µg of β-carotene is equivalent to 1µg of retinol, whilst 24µg of α-carotene is equivalent to 1µg retinol [45]. The iron composition of the common bean was analyzed by flame atomic absorption spectroscopy as described elsewhere [39]. Triplicate analysis for each variety of cooked sweet potato and common bean was conducted to get an average of each micronutrient in each food. Table 1 shows the PVA carotenoid and iron composition of the cooked sweet potato and common bean, respectively used in the study.

Table 1. Provitamin A carotenoid (retinol activity equivalent), and iron composition of study cooked sweet potato and common bean, respectively used in the study

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>OFSP/100g</th>
<th>WFSP/100g</th>
<th>IBCB/100g</th>
<th>NIBCB/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>β-carotene (µg)</td>
<td>36900</td>
<td>9200</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>α-carotene (µg)</td>
<td>300</td>
<td>110</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>Vitamin A (µgRAE)</td>
<td>3088</td>
<td>711</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>Not tested</td>
<td>Not tested</td>
<td>9.3</td>
<td>5.1</td>
</tr>
</tbody>
</table>

OFSP: Orange fleshted sweet potato; WFSP: White fleshted sweet potato; IBCB: Iron biofortified common bean; NIBCB: Non-iron biofortified common bean; RAE is Retinol activity equivalent (retinol); RAE = β-carotene (µg/100 g)/12+ α-carotene (µg/100 g)/24 [45].

Measurement of sensory acceptability

Sensory acceptability was measured by the sensory evaluation method. The sensory evaluation sessions were held in a room with separate, isolated closets set up for each panelist. Each panelist received a spoon and a small polystyrene cup containing the control composite dish, approximately 50g of NIBCB combined with 50g WFSP (WFSP+NIBCB), and the test composite dish, approximately 50g of IBCB combined with 50g of OFSP (OFSP+IBCB). To prevent lactating mothers from making judgments based on labels, the samples were given random numbers as labels. The purpose of this was to ensure that panelists relied solely on their sensory experiences [46]. To achieve this, the samples were randomly labeled with a unique three-digit code obtained from a table of random numbers and were served in a random sequence [46]. The samples were warmed in a microwave oven for 10 seconds, at medium heat, before serving. The lactating mothers were provided with a cup of water to rinse their palates between evaluating samples. Before each session, the sensory attributes of color, texture, aroma, taste, and overall acceptance were explained to the panelists (lactating mothers). An equally spaced five-point facial hedonic scale with ratings (1=“dislike very much”; 2= “dislike”; 3=“neither like nor dislike”; 4=“like”; 5= “like very much”). This rating scale was chosen because it is recommended for persons with lower literacy levels [41]. It is worth noting that longer hedonic scales, such as those with 7 or 9 ratings, tend to confuse subjects with lower literacy levels, while rating scales that are shorter than the five-point scale tend to cause end-point avoidance [41]. It is worth noting that the WRA in the study district has lower literacy
levels, with 67% of children dropping out of school before completing ordinary-level education [47]. This coupled with low literacy levels established during the pilot study justifies the use of the 5-point rating scale in the study participants as recommended by Stone and Sidel [41]. Each sensory attribute was described on the form with an accompanying facial hedonic scale. The ratings of the hedonic scale were verbally explained to the panelists in the local language, at the sensory evaluation sessions. The participants were asked to rate the acceptance of each attribute by marking the appropriate response on the facial hedonic scale. A sensory attribute was considered acceptable if it was rated as “like to like very much”

**Measurement of perceptions**

Qualitative data (perceptions) were collected using a focus group discussion (FGD) guide. Focus group discussions (FGDs) were conducted to explore the lactating mothers' perceptions to understand the factors that may motivate them to consume the test composite dish (OFSP+IBCB). The FGDs were conducted about 30 minutes after the sensory evaluation study was completed. All the 94 lactating mothers who participated in the sensory evaluation study were eligible to participate in the FGDs. Through established community relationships, four facilitators, experienced in conducting FGDs in the local language (Lhukonzo) were recruited for two days of training in focus group moderation concerning the specifics of this research study following guidelines explained elsewhere [48]. A trained facilitator directed the discussions, using an unstructured FGD guide. The FGD guide consisted of a brief explanation of the samples that were tasted during the sensory evaluation as well as the question for initiating and facilitating the discussion. Guidelines for conducting FGDs with a structured set of open-ended questions were followed, as recommended elsewhere [49]. The open-ended question was “You have participated in the sensory evaluation of OFSP combined with IBCB. What would motivate you to consume the IBCB+OFSP composite dish?” Furthermore, the facilitators used probes such as “Would you explain further?” and “Would you give an example?” where it was deemed necessary. The FGDs were facilitated in the local language (Lhukonzo) by trained FGD facilitators. A digital voice recorder was used to record the FGDs after participants consented to the use of the voice recorder. A sample size for a FGD between 7 and 12 participants is appropriate for a qualitative nutrition-related study [50]. Therefore, each focus group included 8 to 10 participants. The FGDs were conducted until data saturation was reached. Data saturation means that researchers aren't finding any additional data from FGDs [51].

**Analysis of quantitative data generated from sensory acceptability measurements**

The proportion (percentage) of lactating mothers was calculated according to their sensory attribute ratings for the control composite dish (WFSP+ NIBCB) and test composite dish (OFSP+IBCB). A sensory attribute was considered acceptable if it was rated as good to very good by the lactating mothers. A binary outcome of yes/no was created for sensory acceptability. A chi-square statistical test was used to test for significant differences in the sensory attributes (taste, color, aroma, texture, and general acceptability) between the control and test composite dishes. A chi-square test was considered significant at a p-value of less than 0.05. Statistical data analysis was done by STATA, version 15.1.
Analysis of qualitative data generated from focus group discussions

Qualitative data generated from FGDs was analyzed using thematic analysis by following the six steps including familiarization of data; coding of data; generating of themes; reviewing of themes, defining and naming of themes; and writeup [52]. Thematic analysis is a method for identifying, analyzing, and reporting patterns (themes) within data. Instead of starting with predetermined themes based on theory or existing knowledge (deductive thematic analysis), this study used an inductive thematic analysis approach, where the themes were determined by the data itself. Table 2 shows the description of the six steps used during the thematic analysis of data generated from the FGDs as recommended by Braun and Clarke [52].

Table 2. Description of the six steps for inductive thematic analysis used in the study.

<table>
<thead>
<tr>
<th>Steps</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiarization with data</td>
<td>A verbatim transcription was done. Verbatim transcription is a word-for-word transcription of a recording. The verbatim transcription was later translated from the local language (Lhukonzo) into English by the three FGD facilitators. The translated recordings were cross-checked by a Lhukonzo native speaker and a professional teacher against the English translation, for accuracy</td>
</tr>
<tr>
<td>Generating initial codes</td>
<td>The translated data was organized (coded) systematically throughout the complete set of data and gathering data that is pertinent to each code.</td>
</tr>
<tr>
<td>Searching for themes</td>
<td>The codes were organized into potential themes by gathering all data relevant to each potential theme.</td>
</tr>
<tr>
<td>Reviewing themes</td>
<td>Checked if the themes worked regarding the coded extracts and the entire data set, to enable generate a thematic ‘map’ of the analysis</td>
</tr>
<tr>
<td>Defining and naming themes</td>
<td>Ongoing analysis from three independent researchers to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.</td>
</tr>
<tr>
<td>Producing the report</td>
<td>Thereafter, a discussion was written for each theme relating to the analysis of the research question</td>
</tr>
</tbody>
</table>

Ethical considerations

The study was performed following the ethical standards as laid down in the 1964 Declaration of Helsinki. Ethical approval was granted by The AIDS Support Organisation Research Ethical Committee (Reference number TASO-2023-252). Informed and signed consent were obtained individually from the lactating mothers attending the postnatal clinic of Bwera General Hospital, Kasese district, Western Uganda.

Results

Background characteristics of study participants
A total of 94 eligible lactating mothers completed both the sensory evaluation study and FGDs. The mean age of the caregivers was 25.6 years. Only 36% of the lactating mothers had at least completed primary level education while 37% and 63% of the mothers had infants, 1 to 5 months and 6 to 23 months, respectively.

**Sensory evaluation and acceptability of study composite dishes**

The proportion of participants who scored the study composite dishes on a 5 hedonic scale

For the test composite dish (IBCB+OFSP), a high proportion of lactating mothers at 83%, 38.3%, 50%, 58.5%, and 45.7% gave a score of like very much (5), like much (4), like very much (5), like very much (5), like very much (5) for the color, texture, aroma, taste, and overall acceptability, respectively. Table 3 shows the proportion of lactating mothers who scored the study composite dishes.

**Table 3.** The proportion of lactating mothers who gave different ratings for the sensory attributes study composite dishes

<table>
<thead>
<tr>
<th>Composite dish</th>
<th>Attributes</th>
<th>Dislike very much n(%)</th>
<th>Dislike n(%)</th>
<th>Neither like nor dislike n(%)</th>
<th>Like much n(%)</th>
<th>Like very much n(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFSP+IBCB</td>
<td>Color</td>
<td>0(0)</td>
<td>0(0)</td>
<td>1(1.1)</td>
<td>15(16)</td>
<td>78(83)</td>
</tr>
<tr>
<td></td>
<td>Texture</td>
<td>2(2.1)</td>
<td>10(10.6)</td>
<td>32(34)</td>
<td>36(38.3)</td>
<td>14(14.9)</td>
</tr>
<tr>
<td></td>
<td>Aroma</td>
<td>0(0)</td>
<td>1(1.1)</td>
<td>16(17)</td>
<td>30(31.9)</td>
<td>47(50)</td>
</tr>
<tr>
<td></td>
<td>Taste</td>
<td>1(1.1)</td>
<td>4(4.3)</td>
<td>3(3.2)</td>
<td>31(32.9)</td>
<td>55(58.7)</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0(0)</td>
<td>2(2.1)</td>
<td>19(20.2)</td>
<td>30(31.9)</td>
<td>43(45.7)</td>
</tr>
<tr>
<td>WFSP+NICB</td>
<td>Color</td>
<td>2(2.1)</td>
<td>4(4.3)</td>
<td>17(18.5)</td>
<td>51(54.3)</td>
<td>20(21.3)</td>
</tr>
<tr>
<td></td>
<td>Texture</td>
<td>0(0)</td>
<td>4(4.3)</td>
<td>24(25.5)</td>
<td>46(48.9)</td>
<td>20(21.3)</td>
</tr>
<tr>
<td></td>
<td>Aroma</td>
<td>2(2.1)</td>
<td>4(4.3)</td>
<td>12(12.8)</td>
<td>53(56.4)</td>
<td>23(24.5)</td>
</tr>
<tr>
<td></td>
<td>Taste</td>
<td>0(0)</td>
<td>9(9.6)</td>
<td>3(3.2)</td>
<td>41(43.6)</td>
<td>41(43.6)</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>1(1.1)</td>
<td>12(12.8)</td>
<td>10(10.6)</td>
<td>44(46.8)</td>
<td>26(27.7)</td>
</tr>
</tbody>
</table>

OFSP+IBCB: A combination of orange-fleshed sweet potato and Iron biofortified common bean; WFSP+NICB: A combination of white-fleshed sweet potato and non-iron biofortified common bean
Furthermore, in the control composite dish (NIBCB+WFSP), a high proportion of lactating mothers at 54.3%, 48.9%, 56.4%, and 46.4% gave a score of like much (4) for color, texture, aroma, and general acceptability, respectively. However, 41% scored taste either like much or like very much.

Sensory acceptability of the study composite dishes

A binary outcome for acceptability (yes or no) was created for each sensory attribute. An attribute was considered acceptable if the lactating mother scored it either 4 (like much) or 5 (like very much) on the 5-point hedonic facial scale. Table 3 shows the results from the chi-square test for the association between each sensory attribute of the study composite foods and acceptability.

Table 4: Association between sensory attribute and acceptability of study composite foods

<table>
<thead>
<tr>
<th>Sensory attribute</th>
<th>Acceptable</th>
<th>Chi-square</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=94 across rows</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes, n(%)</td>
<td>No, n(%)</td>
<td></td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td></td>
<td>21.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>OFSP+IBCB</td>
<td>93(98.9)</td>
<td>1(1.1)</td>
<td></td>
</tr>
<tr>
<td>WFSP+NIBCB</td>
<td>72(76.6)</td>
<td>22(23.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td></td>
<td>5.78</td>
<td>0.02</td>
</tr>
<tr>
<td>OFSP+IBCB</td>
<td>50(53.2)</td>
<td>44(46.8)</td>
<td></td>
</tr>
<tr>
<td>WFSP+NIBCB</td>
<td>66(70.2)</td>
<td>28(29.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Aroma</strong></td>
<td></td>
<td>0.04</td>
<td>0.851</td>
</tr>
<tr>
<td>OFSP+IBCB</td>
<td>77(81.9)</td>
<td>17(18.1)</td>
<td></td>
</tr>
<tr>
<td>WFSP+NIBCB</td>
<td>76(80.9)</td>
<td>18(19.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Taste</strong></td>
<td></td>
<td>0.89</td>
<td>0.344</td>
</tr>
<tr>
<td>OFSP+IBCB</td>
<td>86(91.5)</td>
<td>8(8.5)</td>
<td></td>
</tr>
<tr>
<td>WFSP+NIBCB</td>
<td>82(87.2)</td>
<td>12(12.8)</td>
<td></td>
</tr>
<tr>
<td><strong>General acceptability</strong></td>
<td></td>
<td>0.12</td>
<td>0.73</td>
</tr>
<tr>
<td>OFSP+IBCB</td>
<td>73(77.7)</td>
<td>21(22.3)</td>
<td></td>
</tr>
<tr>
<td>WFSP+NIBCB</td>
<td>71(75.5)</td>
<td>23(24.5)</td>
<td></td>
</tr>
</tbody>
</table>

OFSP+IBCB: A combination of orange-fleshed sweet potato and Iron biofortified common bean;
WFSP+NIBCB: A combination of white-fleshed sweet potato and non-iron biofortified common bean
The color of OFSP+IBCB was more significantly accepted than that of WFSP+NIBCB (P<0.0001). In contrast, the texture of WFSP+NIBCB was significantly more accepted than that of OFSP+IBCB (P=0.02). However, there was no significant difference in acceptability between OFSP+IBCB for the other attributes including aroma (P=0.851), taste (P=0.344), and general acceptability (P=0.73).

**Perceptions on the consumption of study composite foods**

Data saturation was achieved on the seventh FGD. Six key themes emerged reflecting issues important for the future consumption of OFSP+IBCB. These themes included sensory acceptability; feasibility to prepare; availability; affordability; sustainable supply and; nutritional value and health benefits of OFSP+IBCB.

**Sensory acceptability**

The majority of lactating mothers reported no barriers to choosing OFSP+IBCB for sensory reasons. However, some mothers reported that they would find it difficult to choose OFSP because of its soft texture. Below are the different perceptions of lactating mothers based on the sensory attributes of color, aroma, texture, and taste.

**Color**

The Orange color of the OFSP which was a component of the OFSP+IBCB dish was attractive to the lactating mothers. They perceived that their children would also accept it if allowed to access it. Besides, they noted that the color of the IBCB and NIBCB in the OFSP+IBCB dish and WFSP+NIBCB dish was not different, respectively. However, they noticed a difference in the color of sweet potatoes in the two study dishes.

“*That dish which had the yellow sweet potato was very attractive, it can stimulate appetite at first sight*” (A mother of a 1-month-old baby)

“I did not notice any difference in the color of beans between the two dishes. However, I noticed the yellow color of the sweet potatoes in one dish and the white color of the sweet potatoes in the other dish. For sure this bright yellow color attracts you to eat this food. I like it” (A mother of a 3-months-old baby).

“......the beans used to prepare the two dishes are similar in color. It is the sweet potatoes that are different in color. Please health worker, tell us where that yellow sweet potato is accessible. I am sure my twins will like it because of that attractive bright yellow color” (A mother of 7-month-old twins).

“I would prefer OFSP to WFSP because the yellow color for OFSP is attractive to my child. I say this because my child likes to eat cooked pumpkin probably of its yellow color. Currently, my child eats the same food we prepare as a family. Therefore, I would buy the OFSP to prepare for all the household members including myself and my child to enjoy. For the common beans, they look the same, I would just buy whatever I find on the market” (A mother of a 16-month-old child).
Texture

The majority of lactating mothers complained of the soft texture in OFSP compared to the WFSP. However, they noted that this soft texture they observed in OFSP would be good for their children during complementary feeding. In contrast, they noted that the texture of IBCB and NIBCB was similar.

“... this OFSP is not bad. However, it has a very soft texture compared to our WFSP. If the plant breeders can work on improving the texture of OFSP, then it would be the best“ (Mother of a 3-month-old infant)

“This OFSP is too soft compared to the WFSP. I guess this soft OFSP would be good for preparing complementary foods for our children” (A mother to 9-month-old baby)

Feasibility to prepare IBCB and OFSP

The mothers noted they would use the IBCB+OFSP if they would cook quickly, and they had adequate time, and skills to prepare them.

“... you see the problem with common beans, they take a long time to cook. You need to wait a little longer until they are ready. Sometimes you have a rush program, you can't wait for the beans that cook for over four hours. I will need to know whether the IBCB get cooked faster compared to our conventional beans” (mother of a 6-month-old infant)

“Recently we have to share our time between cooking and our jobs. So we need something which cooks quickly to leave at home for the household members, and for me to pack in my container for lunch while at my place of work. I would use the IBCB if they take a shorter period to cook compared to our conventional common bean. We no longer eat conventional common beans at home because it takes longer to cook. Sweet potato is fine it cooks faster either by boiling or steaming”(Mother of a 9-month-old baby).

“Common bean takes longer to cook compared to sweet potato, you waste a lot of time waiting for it to get ready. In the long run, you waste a lot of fuel on it. On average, how many hours does that IBCB variety take to get ready if you cook it on a full medium charcoal stove?” (Mother of 10 months old baby).

Some mothers wondered whether the cooking methods for IBCB and OFSP are similar to those they use to cook NIBCB and WFSP

“Are the IBCB and OFSP require different cooking methods and skills to prepare them for eating or they are cooked the same way as our locally available WFSP and NIBCB? Please let us know” (A teenage mother of a 6 months old infant)

“.... I am pretty sure that the local methods we use to cook WFSP and NIBCB are not any different from those we have to use while cooking OFSP and IBCB, respectively”(A mother of a 13-month-old child)
“Common bean remains common bean irrespective of variety. We usually cook by boiling it with either prior soaking or no prior soaking. Even you can remove the seed coat before boiling. The same way with sweet potatoes, whether WFSP or OFSP they are all sweet potatoes. The commonly used methods to cook sweet potatoes are either boiling or steaming” (A mother with an 11-month-old infant)

**Availability of IBCB and OFSP**

The majority of mothers showed interest in knowing the market where they could find the OFSP and IBCB.

“......... tell us where that yellow sweet potato can be found to buy it. I am sure my twins will like it because of that attractive bright yellow color” (A mother of 7-month-old twins).

“Where would one find the vines for the OFSP and seeds for IBCB if one wants to plant them? This would help me grow them myself instead of buying them from the market” (A mother to a 10 months old infant)

**Affordability of IBCB and OFSP**

The lactating mothers expressed the issue of affordability of IBCB and OFSP and the majority noted that they would consume them if they were cheaper to purchase from the market, produce in the gardens, and cook before eating.

“How much is the cost of IBCB and OFSP each? Is it cheaper than our locally available NIBCB and WFSP? I would buy for household consumption if it is offered at an affordable price” (Mother of a 10-month-old infant)

“Cooking common bean is very expensive because it consumes a lot of fuel. Common bean takes a long time to cook hence it consumes a lot of fuel such as charcoal and firewood which we usually use for cooking here. We need common bean which cooks fast to save fuel” (A mother of an 11-month-old infant)

“How much could the vines and seeds for OFSP and IBCB cost, respectively if someone wanted to plant them? You see for us we are used to plant WFSP and NIBCB. I have picked interest in growing both IBCB and OFSP, but where can I access the seeds and vines, respectively for planting? I need to give them a try” (A mother of an 18-month-old child)

“.... growing would be good, but it might be expensive in the long run if those IBCB and OFSP are easily attacked by pests and diseases or are not drought resistant” (Mother to a 6-month-old infant)

“...those newly introduced genetically modified biofortified foods are not like our local breeds. They are easily attacked by pests and diseases. So it means that you will have to buy pesticides. That means incurring more costs. Our conventional NIBCB and WFSP are usually grown minus applying pesticides. Are these IBCB and OFSP pest resistant? (Mother to a 21-month-old child)
Sustainable supply of IBCB and NIBCB

The majority of lactating mothers raised a concern about a sustainable supply of the IBCB and OFSP in the food supply chain.

“….. I would consume the OFSP and IBCB if I could find it on the market always for me to buy. The challenge is to go to the market and you don’t find it whenever you want it” (A mother to a 16-month-old child)

“You see some time back (I think 2 years back), the Ministry of Agriculture officials introduced some common beans in our community. They told us they are nutritious and give a high yield. However, I was demoralized when I looked for seeds on the market for three consecutive seasons to plant them, and I could not find them. How I wish you let us know where we could find these seeds for OFSP and IBCB so that we can plant them season after season”

“…….. Some of us are working mothers, we usually eat away from home in places such as restaurants. I wonder whether the restaurant people can cook OFSP and IBCB as they do for NIBCB and WFSP so that people who eat away from home can consume the OFSP and IBCB from such eating outlets” (A mother to 22 month-old baby)

Nutritional value and health benefits

The majority of mothers suggested that they would buy and consume OFSP if they knew that their nutritional value and health benefits were superior to that of OFSP. However, they noted that the nutritional value and health benefits for IBCB and NIBCB were similar.

“You see OFSP is very soft with many threadlike fibers compared to WFSP. For sure it isn't appetizing to eat OFSP. I will only choose it if I am sure that it is more nutritious than WFSP” (A mother to an 11-month-old infant)

“…. I will only consider eating OFSP combined with either IBCB or NIBCB if I know that OFSP has more health benefits than WFSP. My reason is that OFSP is too soft compared to WFSP. However, IBCB and NIBCB are very similar in every sensory attribute and nutritional value. So I can choose any available to eat as a soup with OFSP” (A mother to a 9-month-old infant)

“…. I meant that IBCB and NIBCB appear similar in everything such as color, shape, size, and taste. Because of this similarity, nutritional value is also the same. So I would choose any of the common bean varieties I find on the market” (A mother to a 9-month-old infant)

“….yes, I think OFSP has nutrients that have health benefits such as good eyesight because of its yellowish color similar to carrots. During the immunization visits of my firstborn, health workers taught us that foods with yellow color such as carrots are good for eyesight. I would also consume OFSP probably
because of its yellow color and the associated health benefits for eyesight” (A mother to 3-month-old infant)

Discussion

This study explored lactating mothers' perceptions and sensory acceptability of a PVA carotenoid-iron-rich composite dish prepared from a combination of OFSP and IBCB. A combination of WFSP and conventional NIBCB is commonly consumed in Uganda. However, this combination is low in PVA carotenoids and iron. The retinol activity equivalent (RAE) + iron composition in OFSP + IBCB (test food) and WFSP + NIBCB (control food) used in this study was 3088µgRAE + 9.3mg/100g and 711µgRAE = 5.1mg/100g, respectively (Table 1). The RDA for iron and retinol for lactating women is 9.5mg/day and 1300µgRAE, respectively [5, 9, 11]. Therefore, approximately 100g of IBCB and only 42g from OFSP + IBCB would be needed to meet the RDA requirements for iron and retinol required for lactating mothers. In contrast, nearly 200g of NIBCB and 200g of WFSP from WFSP + NIBCB would be needed to meet the RDA requirements for iron and retinol required for lactating mothers. This suggests that compared to the WFSP + NIBCB, only a small portion of OFSP + IBCB is needed to meet RDA requirements for iron and retinol for lactating mothers.

To our knowledge, this is the first attempt to understand the maternal acceptability of homemade composite dishes prepared from foods biofortified with PVA carotenoid and iron versus the low iron-PVAC dishes prepared from conventional foods in Uganda. In this present study, the color of the IBCB + OFSP dish was highly significantly accepted compared to that of the NIBCB + OFSP dish probably because of the deep orange color of the OFSP which was attractive to the lactating mothers as they reported in the FGDs. In contrast, the lactating mothers seemed not to recognize any color difference between IBCB and NIBCB, as they emphasized during FGDs that every sensory attribute was similar between IBCB and NIBCB. Therefore, the color acceptability of OFSP + IBCB could have been attributed to the color of OFSP but not IBCB. This finding is similar to the previous studies which reported that PVA biofortified foods such as OFSP and either yellow maize or cassava were acceptable to the potential consumers because of the attractive deep orange color in the former and yellow color in the latter [53–56]. It is worth noting that the orange and yellow colors observed in PVA biofortified foods including OFSP are due to the increased PVA carotenoids added to these staples during biofortification [57]. Findings from this present study confirm that the yellow or orange color observed in PVA biofortified foods improves the acceptability of other foods if they are combined with other foods with less attractive colors. In South Africa Govender and colleagues demonstrated that because of the appealing color of OFSP and yellow PVA biofortified maize, consumers’ acceptability and positive perceptions were high when they were served other non-biofortified foods if they were combined with either OFSP or PVA biofortified maize [56]. However, it is worth noting that this present study used a test composite dish prepared from a combination of OFSP and IBCB.

Besides, during FGDs, mothers raised a suggestion of the likelihood of their children's acceptability of the complementary food prepared from the common bean and OFSP because of the attractive color they
observed in OFSP. Such suggestions from lactating mothers confirm that lactating mothers are gatekeepers of complementary foods (CFs) they feed their children [58, 59]. Moreover, previous studies have shown that based on the appealing yellow or orange observed in PVA biofortified foods, caregivers have shown interest in preparing CFs using PVA biofortified foods [53, 54]. The lactating mothers’ suggestions may also indicate the necessity of developing an innovative complementary food blend rich in PVA carotenoids and iron from OFSP + IBCB and testing its acceptability among their children. The lactating mothers’ suggestion is plausible because children, 6 to 23 months in low-income countries such as Uganda are at a higher risk of developing ID and VAD since they are predominantly fed CFs that are low in iron and vitamin A [29, 60, 61]. Moreover, developing and testing child acceptability of PVA carotenoid-iron-rich CFs and testing its acceptability among children in the age range of complementary feeding is feasible [62].

The texture of IBCB + OFSP was not acceptable to the lactating mothers compared to that of NIBCB and WFSP (P = 0.02). The unacceptability of the IBCB + OFSP dish was linked to the soft texture in the OFSP but not IBCB as study participants indicated during the FGDs that the sensory properties of IBCB and NIBCB were similar. This finding is not surprising because the majority of OFSP varieties released in low and middle-income countries including Uganda have high moisture content compared to the WFSP [33, 63], hence their softness. The softness reported by lactating mothers in this present study indicates the necessity of increasing the dry matter content of OFSP. Moreover, it is feasible to increase the dry matter content of OFSP [64]. In contrast, during the FGDs, lactating mothers used the softness of OFSP as a justification for the potential use of OFSP as a complementary food for their children. This justification is plausible because it is recommended that CFs should be soft to prevent child choking [58].

Aroma, taste, and general acceptability were scored highly by the lactating mothers and not significantly different between OFSP + IBCB and WFSP + NIBCB. Such findings indicate the potential of replacing conventional WFSP + NIBCB with OFSP + IBCB. Similar findings have been reported in South Africa [56]. However, the South African study did not have a composite dish having a combination of IBCB and OFSP as it only focused on the traditional composite dishes prepared with either OFSP or PVA biofortified maize [56]. Moreover, the South African study recruited adult males and females [56], compared to this present study which recruited lactating mothers, a target group with high physiological demands for iron and vitamin A [4, 5].

During FGDs, some mothers showed interest in knowing where they would access the vines and seeds for OFSP and IBCB, respectively so that they could grow them for their home consumption, and even sell the excess to improve their incomes. These findings indicate the possibility of adopting the use of study biofortified foods in the study participants. Similar findings of the potential to adopt the growing OFSP have been reported elsewhere in Eastern Uganda [65]. Moreover, the adoption of IBCB has the potential to improve household consumption of IBCB [66].

Considering the feasibility of preparing OFSP and IBCB, mothers were worried about the long cooking time for common beans and the high cost of fuel associated with cooking common beans. This finding is
consistent with previous studies conducted in Uganda, which showed that consumers were afraid to use common beans because of their long cooking time and high fuel consumption [59], or they preferred common bean processing methods that reduce the cooking time of common bean and hence save fuel [67]. It is worth noting that the cooking time for NIBCB and IBCB used in this present study during the preparation of the study composite dishes was approximately 1.5 hours and 3.5 hours, respectively. Such a high cooking time observed for IBCB compared to NIBCB would prevent the lactating mothers from cooking IBCB for household consumption. However, the peer mothers who prepared the study composite dishes first soaked common beans before cooking them. This was plausible because cooking IBCB with prior soaking may reduce the cooking time of common bean [68].

During FGDs, some mothers indicated that they would consume OFSP + IBCB if they knew that they were nutritious or if eating them would provide any health benefits. For example, one study participant emphasized that she would consume a combination of OFSP and IBCB because she knew from a previous nutrition education program that the OFSP provided health benefits to the eye. This finding informs that there is a need to promote the consumption of biofortified foods such as OFSP and IBCB through community nutrition education. The education messages should focus on the nutritional value of biofortified foods and the health benefits of their consumption. It is worth noting that previous studies have shown that the sensory acceptability and willingness to pay for biofortified foods may be improved through nutrition and health promotion program activities such as providing information, education, and communication about the nutritional and health benefits of eating biofortified food crops such as biofortified yellow cassava and IBCB [69–71]. For example in Rwanda, sensory acceptability of IBCB was higher among consumers who had prior sensitization and awareness about the nutritional benefits of consuming IBCB [72].

**Conclusions**

The PVA carotenoid-rich sweet potato, OFSP served with a high iron common bean, IBCB (OFSP + IBCB) was significantly accepted for color but not texture compared to the low PVA conventional sweet potato, WFSP served with the low iron conventional common bean, NIBCB (WFSP + NIBCB). However, for overall acceptability, OFSP + IBCB and WFSP + NIBCB were equally acceptable, suggesting that the biofortified, OFSP + IBCB dish has the potential to replace the staple non-biofortified, WFSP + NIBCB dish among lactating mothers in the study area. Lactating mothers had positive perceptions of using OFSP and IBCB if they could cook fast, and provide health benefits upon consumption, with a stable availability and economic access in the food supply chain.

**Declarations**

**Ethics approval and consent to participate**

The study was performed following the ethical standards as laid down in the 1964 Declaration of Helsinki. Ethical approval was granted by the Research Ethical Committee at The AIDS Support Organisation Research Ethical Committee (Reference number TASO-2023-252). Informed and signed
consent were obtained individually from the mothers in the postnatal clinicians who participated in the study. Informed consent was taken from legally authorized representatives and/or guardians of all participants who were below 18 years old and those without formal education.

**Consent for publication**
Not applicable.

**Availability of data and materials**
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Competing interests**
The authors declare that they have no competing interests.

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**Authors’ contributions**
“Conceptualization, EB; K.P.; ST.; and M.S.; Methodology, EB; KP; MS; and; BMM.; software, EB.; validation, EB; KP; ST;MS; formal analysis, EB.; investigation, EB; BMM; JS.; Resources; BMM.; Data curation, BE.; Writing—original draft preparation, EB; writing—review and editing, EB; KP; ST; MS; BMM; EBI; and JS.; supervision, KP; MS; ST; and EB.; project administration, EB.; funding acquisition; KP; MS; and ST. All authors have read and agreed to the published version of the manuscript.”

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**Figures**

![Test and control composite dishes](image)

**Figure 1**

Test and control composite dishes prepared from sweet potato and common bean.

**Test composite dish (OFSP+IBCB)**

**Control composite dish (WFSP+NIBCB)**

OFSP+IBCB: A combination of Orange fleshy sweet potato and iron biofortified common bean; WFSP+NIBCB: A combination of white fleshy sweet potato and non-iron biofortified common bean.