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Amylase increases energy and nutrient density of Super Cereal Plus porridge as prepared and accepted by Rwandan caregivers

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Abstract

Adding amylase to Super Cereal Plus (SC+A) improves energy and nutrient intake as porridge energy density reaches 1.0 kcal/g, meeting the recommended ≥0.8 kcal/g for prepared foods for young children. Caregiver response to SC+A in terms of adjusting porridge preparation using printed pictogram instructions was not yet investigated. The study assessed (a) porridge preparation by caregivers; (b) porridge energy density; (c) sensory porridge acceptability; and (d) understanding of preparation instructions. An 8-day follow-up intervention study was conducted amongst caregivers of children aged 6–23 months (n = 238) in Rwanda. Caregivers prepared porridge using SC+A whilst referring to printed pictogram instructions at the study site on Days 1 and 8 and received flour for preparation at home on Days 2–7. At the site, data were collected on porridge preparation procedures, energy density, consistency, acceptability, and interviews (n = 12), and focus group discussions (n = 6) were conducted. Mean porridge dry matter (DM) increased from 21.3 ± 4.4% (Day 1) to 25.1 ± 4.8% (Day 8; $p < 0.0005$). Flour and water were mixed before cooking by 95% of the participants, as per printed instructions. Sensory porridge acceptability was high, and the printed instructions enabled caregivers to prepare an accepted and energy dense porridge. The preferred water/flour volume ratio was 2.5 instead of 3. In conclusion, Rwandan caregivers prepared well-accepted SC+A porridges with a preferred consistency and mean DM content of 25.1% (1.0 kcal/g), after 1 week practicing at home. This supports introducing SC+A with the tested instructions at scale.

KEYWORDS

alpha-amylase, complementary feeding, energy density, porridge preparation, Rwanda, Super Cereal Plus

1 | INTRODUCTION

Super Cereal Plus (SC+), consisting of corn, wheat or rice (52.3–58.3%), soy beans (20.0–25.0%), sugar (9.0%), milk powder (8.0%), oil (3.0–4.0%), and a vitamin–mineral premix, is a fortified blended food that the United Nations (UN) World Food Programme (WFP) developed and has been distributing to beneficiaries in many countries. Porridge is best prepared by mixing the appropriate amount of SC+ flour with clean water followed by a cooking time of 10 min. SC+ porridge is developed for the treatment of moderate acute malnutrition (MAM) in

children aged 6–59 months and as complementary food, in addition to continued breastfeeding, to ensure adequate nutrient intakes for children aged 6–23 months.

In 1992, the importance of enhanced food energy density and feeding frequencies in early child nutrition were demonstrated (Sanchez-Grinan, Peerson, & Brown, 1992). Now, more than two decades later, it is widely recognized that energy and nutrient dense foods should be consumed to improve nutritional status and meet energy and nutrient requirements of young children and malnourished children (Dewey, 2013; Golden, 2009). The Codex Alimentarius Commission (CAC), established by the UN Food and Agriculture Organization (FAO) and World Health Organization (WHO), developed guidelines on formulated complementary foods for older infants and young children (FAO/WHO, 2013). The energy density of 4-kcal/g dry matter (DM), recommended by the CAC guidelines (FAO/WHO, 2013), is met by SC+ flour that contains 4.1-kcal/g DM. However, the average energy density of SC+ porridge (0.70 kcal/g—17% DM content porridge) is lower than recommended by the WHO technical note on supplementary foods for the management of MAM (World Health Organization, 2012) and the Codex Standard for processed-cereal-based foods for infants and young children (FAO/WHO, 2006), which both recommend a prepared porridge energy density of at least 0.8 kcal/g. This Codex Standard also indicates the need for a minimum prepared food DM content of 25% (FAO/WHO, 2006).

Adding amylase to gruels is a possible way to achieve a higher food energy density, as more flour can be added to the same amount of water whilst maintaining the same porridge viscosity (thickness). In this way, a higher energy and nutrient intake can be achieved from consuming the same volume of porridge by young children, as mentioned in the CAC guidelines (FAO/WHO, 2013). In 1994, the positive impact of amylase treatment on viscosity control of weaning foods was demonstrated (Stephenson, Gardner, Walker, & Ashworth, 1994). After that, adding amylase to rice–flour oral rehydration solutions was found to increase its energy density (Vettorazzi, Solomons, Brown, & Shoemaker, 1996; Vettorazzi, Mazariegos, Molina, De Ramirez, & Solomons, 1996), but caregivers' ORS home preparation revealed that following the preparation instructions, such as mixing proper amounts of the required ingredients (including alpha-amylase), was a challenge (Hudson, Vettorazzi, Mazariegos, & Solomons, 1996). Multiple studies, where the preparation of amylase-added gruels was controlled, showed the positive impact of amylase addition on energy and nutrient intake by children (Bennett et al., 1999; Brown et al., 1995; Van Hoan, Mouquet-Rivier, Eymard-Duvernay, & Treche, 2010). One randomized controlled trial implemented in Congo concluded that energy intakes from gruels increased in the intervention group that was provided with amylase-containing flour as compared with the control group that was provided with nonamylase containing flour. In this study, the participating caregivers were individually shown what amounts of water and flour to use (Moursi, Mbemba, & Trèche, 2003). The most recent acceptability study (conducted in 2014 by WFP, GRET and DSM) on amylase-added Super Cereal (SC) and SC+ porridges in Burkina Faso amongst children 12–36 months and their caregivers confirmed similar positive impact and high porridge acceptability. Energy intake, and consequently nutrient intake, from the amylase added porridges was increased by 67% amongst children aged 12–23 months old. The provided porridges were prepared by trained field assistants (Kampstra et al., 2017).

Key messages

- After using SC+A for a week, Rwandan caregivers prepared a 25% DM content porridge (energy density: 1.0 kcal/g) that meets the WHO-recommended prepared food energy density of ≥0.8 kcal/g for young children.
- Acceptability of SC+A porridges prepared by caregivers was very good.
- Feasibility of achieving the recommended porridge energy density when providing SC+A, and printed preparation instructions was confirmed.
- Distribution of SC+A should be accompanied by messages on product purpose, target population, and preparation instructions, including the flour:water ratio of 1:2.5, mixing flour and water before cooking and 5-min boiling for food safety.

The recommended preparation instructions for SC+ with amylase (SC+A) are different from those currently used for SC+ porridge preparation, including adjusted recommendations on the proportion of flour and water (flour:water ratio) to guide users in the preparation of an approximately 25% DM content porridge. Moreover, and although this was recommended for SC+ to prevent lumping of flour in porridge already, it is essential that SC+A flour is mixed with water of ambient temperature because amylase will only be active within a certain temperature range before the boiling point. Hence the targeted porridge energy density will not be achieved when adding flour to hot or boiling water. Nevertheless, in different contexts and countries, SC+ users preferred to add flour to already boiling water as it allows them to be away from the cooking place whilst the water is getting ready to boil (unpublished observations). Porridge preparation techniques of caregivers, prepared porridge energy density, and sensory acceptability, and whether the revised porridge preparation instructions of SC+A would be understood, adapted, and accepted by beneficiaries, without additional training and follow-up such as behavioural change communication, was not known.

In order to investigate the feasibility of introducing amylase as a standard ingredient of SC+ in WFP's product specifications, the study objectives were to investigate (a) porridge preparation techniques by caregivers of children aged 6–23 months when provided with preparation instructions in pictograms but without further explanation or example of preparation; (b) DM content and consistency of the prepared porridge; (c) sensory porridge acceptability by caregivers; and (d) overall product acceptability by caregivers. The assessments were done at the study site on Day 1 and Day 8, and in-between, caregivers prepared porridge of SC+A at home.

2 | METHODS

2.1 | Study design

A 1-week follow-up intervention study was conducted amongst caregivers with children aged 6–23 months. To assess whether use of different cooking fuels and prior SC+ preparation experiences influenced SC+A porridge preparation, outcomes, and acceptance, six Study Groups were recruited. Group 1—charcoal users with SC+ experience; Group 2—charcoal users without SC+ experience; Group 3—firewood users with SC+ experience; Group 4—firewood users without SC+ experience; Group 5 (control)—50% charcoal and 50% firewood users with SC+ experience; and Group 6 (control) 50% charcoal and 50% firewood users without SC+ experience. The two control groups, 5 and 6, did not prepare SC+A porridge at the study site on Day 1 to assess the potential influence of having been closely observed whilst preparing porridge on Day 1.

All caregivers (Groups 1–6) visited the study site at baseline (Day 1) and after 1 week of porridge preparation at home (Day 8). On Day 1, all caregivers received information that was generally provided during SC+ distribution in the country (mass sensitisation), including a notification of the product change and recommended SC+A porridge preparation instructions. After that, caregivers in Study Groups 1 to 4 were asked to prepare SC+A porridge at the study site. They received a bag of SC+A, printed preparation instructions (Figure 1), and equipment for preparing porridge. Porridge preparation was followed by a sensory test of self-prepared porridge, and caregivers received a new bag of SC+A to prepare porridge at home from Days 1 to 8. Caregivers in Study Groups 5 and 6 (control) received a bag of SC+A on Day 1 to prepare porridge at home from Day 1 to Day 8. On Day 8, all caregivers prepared SC+A porridge at the study site following the same procedures as on Day 1, followed by a sensory acceptability test. Finally, a random subsample of the caregivers was interviewed or participated in a focus group discussion (FGD) to share their experiences with SC+A, porridge preparation, and instructions.

FIGURE 1 Preparation instructions for SC+A distributed along with the food product

2.2 | Study area

The 3-year one UN Nutrition Joint Programme, led by the government of Rwanda and four UN agencies (United Nations Children's Fund, WHO, FAO and WFP), was a multisectoral approach to accelerate stunting prevalence reduction in selected poor households ("Ubudehe" Categories 1 and 2). As part of this programme, WFP implemented, through support of the government and World Vision, a Complementary Feeding programme in the Rutsiro and Nyamagabe districts. SC+ was distributed for consumption by children aged 6–23 months and SC (different from SC+, just containing corn and soy, oil, sugar and vitamin-mineral premix) for pregnant and lactating women. Food distribution was accompanied by mass sensitisation to raise awareness on different health related topics, including on the importance of ensuring adequate nutrition during the first 1,000 days, hygiene, and family planning. The study was implemented at two health centres participating in the programme, in two different subsectors in the Nyamagabe district, called Cyanika and Tare. These locations were selected based on population density, the possibility for recruiting caregivers who had and had not received SC+ previously, and who were using charcoal and firewood.

2.3 | Study participants

A convenient group size of n = 40 was targeted. In May 2016, caregivers (total n = 238) living in the Nyamagabe District, Rwanda, were recruited on two consecutive days by convenience sampling. Caregivers' inclusion criteria were the following: (a) having a child aged 6–23 months who is used to consuming complementary foods and (b) voluntarily agreed to participate in the study and signed the consent form. Caregivers with and without prior experience with regular SC+ porridge preparation, and who used one of the two predominantly used cooking fuels in their household, that is, charcoal or firewood, were sought. Because the number of caregivers using charcoal was lower than expected, some firewood users were included in the charcoal Study Groups for preparation at the study site, constituting 50% of the participants in these groups. In case more than 40 caregivers per group registered themselves at the study site and were eligible for inclusion, that is, the case for firewood user groups, a random sample was selected. Each enrolled caregiver received a participant

number (1–240), which was written down on a piece of paper and given to the participant.

2.4 | Study team

The study was implemented by World Vision Rwanda in collaboration with WFP. A total of 23 experienced field assistants were hired by World Vision to support data collection. In addition, three permanent World Vision staff and international nutritionists from WFP (B. B.) and World Vision (S. S.) were involved. The study team was trained during a 3-day training, including on the principles of observing (no interference), data recording, interviewing, and FGDs.

The field assistants were randomly assigned to observe specific caregivers, both on Day 1 and Day 8. Data was collected during a morning and an afternoon session, from Monday to Saturday, for two consecutive weeks. Each assistant observed 12 caregivers, both on Days 1 and 8. At each study site, a minimum of three supervisors were available to support the assistants in data collection and quality assurance and to ensure that study procedures were followed.

2.5 | Equipment and supplies

Food grade bacterial alpha-amylase (referred to as amylase) was added to SC+ flour in a ratio of 8 mg/100 g of flour by one of WFP's SC+ manufacturers, targeting an average Bostwick flow rate of 180 mm/30 s at 45°C for a 25% DM content porridge. SC+A was packaged in multilayer metalized laminated bags of 1.5 kg and stored under recommended conditions. To distinguish SC+A from regular SC+, the bags were marked with an "A," and the preparation instructions for regular SC+ on the bags were struck through with a permanent marker. Each caregiver was provided with a charcoal stove and charcoal, or firewood and stones, matches, one cooking pot (1 L), wooden cooking spoon, SC+A, hard-copy laminated preparation instructions for SC+A (Figure 1), water, and two plastic cups for adding flour and water. The study team received data collection forms, notebook, pen, electronic weighing scales (0.1-g precision), thermometers to measure porridge temperature, stopwatches to measure cooking time, and one Bostwick consistometer at each study site. For the sensory tests, plastic cups and spoons were used.

2.6 | Data collection

2.6.1 | Quantitative

Baseline data

A baseline questionnaire was used to collect data on study population characteristics, including caregiver age, sex, education level and socio-economic information, and characteristics of caregiver's child aged 6–23 months, including date of birth and breastfeeding and complementary feeding practices.

Caregiver's health status

Caregiver's health status data, that is, the illness history during the 3 days prior to caregiver's study site visit, were collected prior to further data collection on Day 1 and Day 8.

Porridge outcomes and preparation

A porridge preparation recording form was used to collect porridge preparation techniques and prepared porridge characteristics from caregivers at the study site, including data to calculate porridge DM content and water/flour ratio. Weight (g) of "empty cooking pot + spoon," "flour added," "water added," and "final cooking pot + spoon + porridge at 60°C" were recorded. SC+A flour moisture content (%) was provided by the SC+ manufacturer. Porridge DM content (%) was calculated using the following formula:

$$\text{Porridge DM content} = \frac{\left(100 - \text{"flour moisture content"}\right) \times \text{"weight flour added"}}{\left(\text{"weight cooking pot + spoon + porridge"} - \text{"weight empty cooking pot + spoon"}\right)}.$$

The Bostwick consistometer was used to measure the porridge Bostwick flow rate ranging from 0 to maximum 240 mm/30 s at 45°C, as an indicator of porridge consistency.

1-week recall

On Day 8, caregivers were asked to recall how many times they had prepared SC+A at home.

Sensory acceptability

Sensory acceptability data collection forms were used to assess caregiver's SC+A porridge sensory acceptability, which was ranked on a five-point scale, ranging from 1 (*very bad*) to 5 (*very good*). Field assistants explained the different categories, supported by showing the face-emoticons supporting the five different acceptance levels (e.g., "very good"—very happy face emoticon) and asked the caregiver specific questions to assess their acceptability on colour, consistency, smell, taste, and overall. All caregivers evaluated the following: (a) their self-prepared porridge on Days 1 and 8 and (b) only on Day 8, two additional porridges as prepared by trained field assistants with different DM content (19–30%) and/or Bostwick flow rate (<160 to >200 mm/30 s at 45°C; Table 1).

TABLE 1 SC+A porridge preparation recipes used by trained field assistants, for caregivers' sensory testing of porridges with different DM content and different consistency, on Day 8

Variables	Porridge 1	Porridge 2	Porridge 3	Porridge 4	Porridge 5
DM content (%)	23–27	23–27	23–27	27–30	19–23
Bostwick flow rate (mm/30 s at 45°C)	160–200	>200	<160	160–200	160–200
Flour (g)	115	115	115	120	105
Water (g)	400	400	400	350	430
Warming time (min)[a]	5	6–7	3–4	10	2
Boiling time (min)	5	5	5	5	5

Note. SC+A: Super Cereal Plus with amylase; DM: dry matter.

[a]All porridges were prepared with charcoal. It was possible to achieve these porridge outcomes by adjusting the warming time because amylase is active within a specific temperature range.

2.6.2 | Qualitative

On the basis of the implementation schedule and the study participant numbers, caregivers were randomly selected for the interview, participation in FGD, or neither.

Interviews

One caregiver from each Study Group was randomly selected for the semistructured interview at both study sites, resulting in a total of 12 interviews. The field assistant asked the caregiver questions related to their experience with the SC+A, the preparation instructions, satisfaction with the porridge outcomes, household porridge consumption, and general appreciation of the food. Answers were recorded on paper.

Focus group discussions

For each of the six Study Group, one FGD was conducted with a total of 8–10 caregivers. One field assistant moderated the discussion and was responsible for introducing the different questions and for encouraging caregivers to respond openly and freely. The topics discussed in the FGDs and interviews were similar. A second field assistant was responsible to take notes, and a third field assistant recorded any particular observations such as participation of the caregivers.

2.6.3 | Study procedures

The following study procedures were implemented at both study sites.

Study site set-up

Ten cooking spots were installed with a minimum distance of 2.5 m in-between to prevent interaction between the caregivers during porridge preparation.

Day 1

At the start of Day 1, the field assistants were randomly assigned to one caregiver for whom they ensured that they had signed the consent form and that the baseline questionnaire and health status questionnaire were completed (Groups 1–6). If serious health issues would be reported, for example, fever, they would be referred to the health centre. A trained supervisor explained the study procedures to the group of 10 caregivers that assembled, including that they would be asked to prepare porridge using SC+A at the site using the preparation practices that they would normally use at home to prepare porridge for the child 6–23 months old but further guided by the printed preparation instructions. Moreover, sensitisation messages that were typically part of the complementary feeding programme in the district were also shared, including messages on nutrition in general, hygiene, product purpose, use, handling, and storage.

Only caregivers in Study Groups 1 to 4 were asked to prepare SC+A porridge on Day 1. Caregivers received the equipment for porridge preparation, could take as much firewood or charcoal as they wanted, and they prepared their own cooking spot to enable them to follow usual cooking practices. The field assistant collected data on porridge preparation and outcomes. Once the caregiver had finished cooking, the field assistant removed the cooking pot from the fire, smoothly stirred the porridge, and weighed the cooking pot + spoon + porridge (g) at 60°C. A sample of the porridge was used for the caregiver's sensory evaluation. When porridge temperature reached 45°C, trained supervisors measured the porridge consistency.

Finally, supervisors reviewed all data collection forms for completeness and readability, and caregivers received SC+A for porridge preparation at home.

Day 8

Caregivers were asked about their health status again upon arrival (following same procedures as on Day 1), and data on the porridge preparation frequency at the household was collected using the 1-week recall questionnaire. After this, all caregivers (Groups 1–6) were asked to prepare porridge at the study site, and data were collected using the same procedures as described above for Day 1.

After the caregiver finished porridge preparation and rated its sensory characteristics, four trained field assistants at both study sites prepared two different porridges to further investigate the influence of porridge DM content and thickness on sensory acceptability by caregivers (Table 1). Two porridges, Porridge 1 and another porridge (either number 2, 3, 4, or 5), were systematically allocated to the caregivers. These two porridges were then presented in random order. All 10 caregivers present at the site received the same porridge at the same time. The field assistants were trained to keep distance between the caregivers to prevent interaction.

The semistructured interviews (n = 12) and FGDs (n = 6) were conducted after the sensory tests. At the end of Day 8, caregivers were thanked for their participation and received transportation reimbursement.

2.7 | Data analysis

2.7.1 | Quantitative

For sensory acceptability data of the five different porridges prepared by field assistants, data were excluded from analysis when the prepared porridge was out of the desired range for either DM content or Bostwick flow rate that had been set for the five porridges (Table 1). This was the case for 30 of 102 porridges prepared by field assistants (29.4%). For caregivers' porridge preparation techniques, warming, boiling, and total porridge cooking time were recorded in minutes and seconds on which the categorization of boiling time, that is, 0 min (not boiled), <1 min (1–59 s), 1–4 min (1–4 min and 59 s) and ≥5 min (≥5 min), was based. For analysis of continuous data, all digits were rounded to minutes (i.e., 0 min for 20 s and 1 min for 40 s).

SPSS Statistics (SPSS Inc., 2009) was used to analyse quantitative data. Unrealistic data points or outliers were excluded from analysis. Data were presented as mean ± SD when normally distributed as tested by Kolgomorov–Smirnov (sample size ≥50) and by Shapiro–Wilk (sample size <50). Not normally distributed data were presented as median (IQR) or, when this was not possible due to an insufficient number of data points, as median (min-max).

P value of <0.05 was considered statistically significant. Differences between the different Study Groups for continuous, normally

distributed, data were tested by ANOVA and the independent *t* test. The Kruskall–Wallis *H* test and Mann–Withney *U* test (post hoc) was used for continuous, non-normally distributed, data. In case of the latter, adjusted *p* values as calculated by applying the Bonferroni correction were used. Differences between groups for categorical data was assessed by the Pearson chi square test. To test whether practicing porridge preparation at the household had influenced porridge outcomes for Groups 1 to 4 (i.e., comparing porridge outcomes of Day 1 with Day 8), repeated measures ANOVA test was used for normally distributed continuous data. The McNemar's test was used to investigate this (i.e., difference between Days 1 and 8) for dichotomous data, that is, boiling time categories, checking time, and adding flour to water before putting it on fire.

ANOVA was used to test for differences in the sensory evaluation scores amongst the different Study Groups. If a significant difference was found, Bonferroni post hoc test was used to determine which groups were significantly different. For Study Groups 1 to 4, a difference between porridge acceptability outcomes, between day 1 and 8, was tested by the paired samples *t* test.

2.7.2 | Qualitative

Notes from the interviews, FGDs, and observations were translated from local language into English. Anchor codes were developed to help categorization and theming of the codes. Data were word coded and colour coded based on the content and whether the responses were positive, negative, or neutral. After data coding was completed, the results were grouped using the anchor codes. Codes within each anchor code that reflected similar responses were organized into the same categories. The different categories, each on other topics, were combined into different themes. Finally, a summary of the findings was written based on the key themes that emerged for each Study Group. There were 263 codes, 25 categories, and 6 themes, including "product benefit," "preparation instructions," "preparation techniques/cooking method," "quality of the porridge based on sensory test," "porridge consumption," and "product acceptance and future use."

2.8 | Ethics

Ethical clearance was obtained from Rwanda National Ethics Committee on May 03, 2016, number 541/RNEC/2016. Caregivers signed the informed consent forms before participation. Estimated costs for caregivers' travel to the study sites were compensated by the provision of 3000 frw (approx. 3.75 USD) per visit.

3 | RESULTS

3.1 | Study population characteristics

Out of 457 registered caregivers, who met the selection criteria, 240 were enrolled. Two caregivers did not arrive at the study site on Day 1, resulting in a study population of 238.

All caregivers were female; 95.8% were mother, and 3.8% were grandmother to the child. Caregiver's median age was 31 years, and the main primary source of income was farming or agricultural activities (Table 2). There was a significant difference in child age between Group 2 and Group 6 (p = 0.003). Overall, median child age was 15 months old. Self-reported breastfeeding rates were high, and most of the children were still being breastfed. Median feeding frequency was three times in the previous 24 hr.

3.2 | Caregiver's health status

On Day 1, 13% reported that they had experienced some health issues in the previous 3 days, and this was 7% on day 8 (p = 0.722). The health issues reported did not prevent the caregivers from participating in the study.

3.3 | Porridge preparation techniques and energy density of porridge

On Day 1, caregivers of Study Groups 1 to 4 prepared porridges with no differences in DM content, mean water/flour ratio in weight, nor volume between the groups (Table 3). Total median (IQR) flour added (g) was 192 (91–293). Boiling time was only significantly different between Groups 3 and 4 (p < 0.05). Warming time was significantly higher in the Charcoal Groups 1 and 2 than in the Firewood Groups 3 and 4, and consequently, total cooking time was also significantly higher in the Charcoal Groups 1 and 2 (p < 0.05). Overall, only about a quarter prepared a porridge with a Bostwick flow rate of ≤240 mm/30 s at 45°C (the other porridges were thinner) whilst nearly all caregivers mixed flour with ambient water according to the instructions.

On Day 8, mean water/flour ratio and porridge DM content were not different between the groups that had also prepared porridge on site on Day 1 and the control groups that had not (Table 4). Total median (IQR) flour added (g) was 211 (103–318). Over half of the caregivers prepared a porridge with a Bostwick flow rate of ≤240 mm/30 s at 45°C. Nearly all the caregivers boiled the porridge for 1 min or more. On Day 8, 95.0% of caregivers mixed flour with ambient water.

Comparing the outcomes of Day 1 and Day 8, mean water/flour ratio (in weight) used by caregivers of Groups 1 to 4 significantly decreased over time from mean 4.2 to 3.4, $F(1, 156) = 62.358$, $p < 0.0005$, equal to a water/flour ratio of 2.8 and 2.3 in volume (Table 4). Consequently, caregivers prepared porridge with a significantly higher DM content on Day 8 than on Day 1, $F(1, 154) = 74.308$, $p < 0.0005$. The mean amount of porridge (g) prepared was not different between Days 1 and 8, $F(1, 156) = 3.217$, $P = 0.075$. The number of porridges as prepared by caregivers of Study Groups 1 to 4, with a Bostwick flow rate of ≤240 mm/30 s at 45°C doubled on Day 8 as compared with Day 1. Porridge Bostwick flow rate was significantly lower on Day 8 when the results of the four groups were analysed together, $F(1, 33) = 3.217$, $p = 0.023$, indicating thicker porridges on Day 8.

Between Day 1 and Day 8 (Groups 1 to 4), the boiling time, based on the different categories, was not significantly different for the

TABLE 2 Study population characteristics presented per Study Group and combined

Characteristics	Group 1: SC+ experience, charcoal (*n* = 41)		Group 2: No SC+ experience, charcoal (*n* = 39)		Group 3: SC+ experience, firewood (*n* = 38)		Group 4: No SC+ experience, firewood (*n* = 40)		Group 5: Control, SC+ experience (*n* = 41)		Group 6: Control, no SC + experience (*n* = 39)		Total (*n* = 238)	
Caregiver's characteristics														
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
With SC+ experience	41	100	0	0	38	100	0	0	41	100	0	0	120	50.4
Cooking fuel study site														
Charcoal	41	100	39	100	0	0	0	0	20	48.8	20	51.3	120	50.4
Firewood	0	0	0	0	38	100	40	100	21	51.2	19	48.7	118	49.6
Cooking fuel household														
Charcoal	20	48.8	20	51.3	1	2.6	2	5.0	0	0	10	25.6	53	22.3
Firewood	21	51.2	19	48.7	37	97.4	38	95.0	41	100	29	74.4	185	77.7
Occupation														
Farmer	38	92.7	37	94.9	36	94.7	40	100	39	95.1	39	100	229	96.2
Petty trade	1	2.4	1	2.6	2	5.3	0	0	1	2.4	0	0	5	2.1
Daily labour	1	2.4	0	0	0	0	0	0	1	2.4	0	0	2	0.8
Other	1	2.4	1	2.6	0	0	0	0	0	0	0	0	2	0.8
Highest level of education completed														
None	8	19.5	5	12.8	10	26.3	6	15.0	9	22.0	5	12.8	43	18.1
Primary	27	65.9	30	76.9	22	57.9	31	77.5	28	68.3	28	71.8	166	69.7
Secondary	6	14.6	4	10.3	6	15.8	3	7.5	4	9.8	6	15.4	29	12.2
Socio-economic status[d]														
Level 1-very poor	24[a]	58.5	8[b]	20.5	19[ac]	50	13[bc]	32.5	20[ac]	48.8	6[b]	15.4	90	37.8
Level 2-poor	16	39.0	25	64.1	19	50	18	45.0	20	48.8	22	56.4	120	50.4
Level 3-rich	1	2.4	6	15.4	0	0	9	22.5	1	2.4	11	28.2	28	11.8
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
SC+ experience, months	12	2–22	n/a	n/a	10	2–18	n/a	n/a	9	0–18	n/a	n/a	n/a	n/a
Age, years	27	14–40	30	21–39	33	23–43	31	24–38	30	19–41	32	22–42	31	21–40
Family size	5	2–8	5	3–7	5	2–8	6	4–8	6	3–9	5	2–8	5	2–8
Child's characteristics														
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Sex, female	20	48.8	18	46.2	20	52.6	17	42.5	14	34.1	20	51.3	109	45.8
Exclusively breastfed	37	90.2	35	89.7	38	100	36	90.0	40	97.6	37	94.9	223	93.7
Currently breastfed	37	90.2	34	87.2	37	97.4	36	90.0	37	90.2	36	92.3	217	91.2

(Continues)

TABLE 2 (Continued)

Characteristics	Group 1: SC+ experience, charcoal (n = 41)		Group 2: No SC+ experience, charcoal (n = 39)		Group 3: SC+ experience, firewood (n = 38)		Group 4: No SC+ experience, firewood (n = 40)		Group 5: Control, SC+ experience (n = 41)		Group 6: Control, no SC + experience (n = 39)		Total (n = 238)	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
Age complementary foods introduced, months	6	5–7	7	6–8	6	5–7	7	6–8	6	5–7	7	6–8	6	5–7
Feeding frequency in previous 24-hr	3	1–5	3	1–5	3	2–4	3	2–4	3	2–4	4	3–5	3	2–4
	Median	Min-max	Median	Min-max	Median	Min-max	Median	Min-max	Median	Min-max	Median	Min-max	Median	Min-max
Age, months	16^{ab}	7–23	16^{b}	6–23	15.5^{ab}	6–23	13.5^{ab}	6–23	17^{ab}	7–23	12^{a}	6–23	15	6–23

Note. SC+: Super Cereal plus; IQR: Interquartile range.

[abc] Values within a column with unlike superscript letters were significantly different ($p < 0.05$).

[d] Determined based on national categorization system, "Ubudehe" Level 1 (*very poor*), 2 (*poor*), 3 (*rich*), and 4 (*very rich*).

porridge boiled from 1 to 5 min (p = 0.775), and the porridges boiled for 5 min or more (p = 0.607). Nevertheless, the number of caregivers that boiled a porridge for less than 1 min was significantly different between Days 1 (10.1%) and 8 (2.5%; p = 0.002) and was lower after 1 week of practice. The number of caregivers who mixed flour with ambient water, as recommended, was not different between Day 1 and Day 8 (p = 0.607).

3.4 | Sensory acceptability

Sensory acceptability of SC+A porridge prepared by the caregivers was high with an "overall" mean score of ≥4.4 (Table 5) and was not different between Day 1 and Day 8. The mean "consistency" score was significantly higher on Day 8 (3.9) than on Day 1 (3.5), $t(155) = -5.889$, $p < 0.001$.

Regarding caregivers' evaluation of the five different porridges as prepared by the field assistants (Table 5), the "consistency" score for Porridge 2 was significantly lower compared with Porridge 1 (p = 0.008) and Porridge 3 (p = 0.013). Nevertheless, similar as to the evaluation of caregivers' self-prepared porridges, caregivers' "overall" porridge sensory acceptability was not different for the five porridges with different DM contents (19–30%) and with different Bostwick flow rates (<160 to >200 mm/30 s at 45°C).

3.5 | Qualitative findings

Caregivers indicated that the preparation instructions were clear and easy to understand, practicing porridge preparation helped to prepare a porridge they liked and the use of one cup of flour and 2.5 cups of water was preferred by most of them. Most caregivers said that using one cup of flour and three cups of water made the porridge too thin. The porridge was well accepted amongst caregivers and some caregivers indicated that the SC+A porridge was better than the regular SC+ porridge. Some caregivers indicated that it was easier for them to prepare porridge at the study site than at the household as all the necessary tools were available. Nine out of 12 caregivers said in the interview that the prepared porridge was shared amongst household members, varying from amongst all children to all household members. SC+A was well accepted and caregivers indicated that they would be happy to receive SC+A on a regular basis. They would purchase the product if they would have enough resources. Some caregivers believed that, given the high quality, SC+A would be more expensive than other types of flour, and they thought that it would probably not be affordable.

4 | DISCUSSION

In this study, Rwandan caregivers prepared porridge from SC+A with a mean energy density of 1.0 kcal/g after 1 week of practicing porridge preparation and receiving printed preparation instructions. This meets the recommended energy density of at least 0.8 kcal/g of foods for young children (FAO/WHO, 2006; World Health Organization, 2012), and these findings confirm that addition of alpha-amylase is an effective way to improve energy density of cereal based porridges

TABLE 3 Day 1 SC+A porridge preparation characteristics and porridge outcomes per Study Group and overall

Characteristics	Group 1: SC+ experience, charcoal (*n* = 41)		Group 2: No SC+ experience, charcoal (*n* = 39)		Group 3: SC+ experience, firewood (*n* = 38)		Group 4: No SC+ experience, firewood (*n* = 40)		Total (*n* = 158)		*p* value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Water/flour ratio (g)[c]	4.2	1.1	4.7	1.4	4.1	1.5	4.0	1.0	4.2	1.3	0.050
DM content (%)	20.7	3.8	20.4	4.7	22.0	4.5	22.1	4.5	21.3	4.4	0.199
Bostwick flow rate mm/30s, 45°C[d]	197.2	39.1	184.4	41.2	198.2	30.9	177.4	47.6	189.6	39.6	0.498
Amount porridge prepared (g)	821.0	356.1	837.8	398.9	976.4	312.1	952.0	341.6	896.1	356.9	0.126
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	
Warming time (min)	14[a]	8–20	14[a]	6–22	10[b]	4–16	11[b]	4–18	12	5–19	<0.0005
Boiling time (min)	3[ab]	0–6	4[ab]	1–7	2[a]	0–4	5[b]	1–9	3	0–6	0.017
Total cooking time (min)	18[ab]	9–27	20[a]	12–28	13.5[b]	7.5–19.5	16.5[b]	10.5–22.5	16	8–24	<0.0005
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Bostwick flow rate ≤240 mm/30 s, 45°C	9	22.0	5	12.8	15	39.5	14	35.0	43	27.2	0.033
Porridge not boiled	0	0	0	0	0	0	0	0	0	0	
Boiled for <1 min	6	14.6	3	7.7	4	10.5	3	7.5	16	10.1	
Boiled for 1–<5 min	25	61.0	23	59.0	26	68.4	19	47.5	93	58.9	
Boiled for ≥5 min	10	24.4	13	33.3	8	21.1	18	45.0	49	31.0	
Flour added to water before putting the cooking pot on fire:											0.447
Yes	40	97.6	36	92.3	37	97.4	38	95.0	151	95.6	
No	0	0	2	5.1	1	2.6	0	0	3	1.9	
Before and after	1	2.4	1	2.6	0	0	2	5.0	4	2.5	

SC+A, Super Cereal Plus with amylase; SC+, Super Cereal plus; DM, dry matter; IQR, Interquartile range.

[ab]Values within a column with unlike superscript letters were significantly different ($p < 0.05$).

[c]This is water/flour ratio based on weight (g). To calculate water/flour ratio in volume, divide the water/flour ratio in weight by a factor 1.5 (1 g flour equals 1.5 mL flour).

[d]Bostwick flow rate > 240 mm/30 sec at 45°C were excluded.

TABLE 4 Day 8 SC+A porridge preparation characteristics and porridge outcomes per Study Group and overall

Characteristics	Group 1: SC+ experience, charcoal (*n* = 41)		Group 2: No SC+ experience, charcoal (*n* = 39)		Group 3: SC+ experience, firewood (*n* = 38)		Group 4: No SC+ experience, firewood (*n* = 40)		Group 5: Control, SC+ experience (*n* = 41)		Group 6: Control, no SC+ experience (*n* = 39)		Total (n = 238)		*p* value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Water/flour ratio (g)[d]	3.3	0.9	3.6	0.9	3.2	0.9	3.5	1.0	3.4	1.0	3.5	0.9	3.4	0.9	0.199
DM content (%)	25.6	4.2	23.5	3.3	26.3	5.3	24.8	4.8	25.7	4.9	24.8	5.4	25.1	4.8	0.168
Bostwick flow rate mm/30 s, 45°C[e]	159.3	42.1	180.1	34.1	174.6	37.9	162.9	53.1	165.9	44.0	150.9	56.1	165.2	45.3	0.428
Amount porridge prepared (g)	723.0[a]	237.7	816.2[ab]	257.4	996.4[b]	259.9	844.4[ab]	287.4	787.1[a]	241.6	870.8[ab]	316.7	837.6	277.9	<0.0005
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	
Warming time (min)	12[a]	6–18	13[a]	6–20	11[ab]	7–15	8[b]	2–14	9[b]	5–13	10[ab]	4–16	11	5–17	<0.0005
Boiling time (min)	3[ab]	0–6	4[ab]	2–6	3[a]	0–7	5[b]	1–9	3[a]	0–7	4[ab]	1–7	4	1–7	0.001
Total cooking (min)	16[ac]	9–23	17[a]	13–21	145 [ab]	8.5–20.5	13[bc]	7–19	13[b]	7–19	16[ab]	6–26	15	8–22	<0.0005
Number of porridges prepared at home	8	2–14	7	2–12	9	3–15	7	4–10	8	6–10	7	5–9	8	4–12	0.464
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Bostwick flow rate ≤ 240 mm/30 s, 45°C	26	63.4	15	38.5	24	64.9	25	64.1	24	60.0	18	46.2	132	55.4	0.070
Porridge not boiled	1	2.4	0	0	3	7.9	0	0	0	0	0	0	4	1.7	
Boiled for <1 min	0	0	0	0	3	7.9	0	0	2	4.9	3	7.7	8	3.4	
Boiled for 1–<5 min	28	68.3	21	53.8	25	65.8	20	50.0	29	70.7	23	59.0	146	61.3	
Boiled for ≥5 min	12	29.3	18	46.2	7	18.4	20	50.0	10	24.4	13	33.3	80	33.6	
Flour added to water before putting the cooking pot on fire:															0.092
Yes	37	90.2	34	87.2	37	97.4	39	97.5	40	97.6	39	100	226	95.0	
No	4	9.8	4	10.3	0	0	0	0	1	2.4	0	0	9	3.8	
Before and after	0	0	1	2.6	0	0	1	2.5	0	0	0	0	2	0.8	

Note. SC+A: Super Cereal Plus with amylase; SC+: Super Cereal plus; DM: dry matter; IQR: interquartile range.

[abc]Values within a column with unlike superscript letters were significantly different ($p < 0.05$).

[d]Water/flour ratio based on weight (g). To calculate water/flour ratio in volume, divide the water/flour ratio in weight by a factor 1.5 (1 g flour equals 1.5 mL flour).

[e]Bostwick flow rate >240 mm/30 s at 45°C were excluded.

TABLE 5 Caregivers sensory SC+A porridge evaluation on "colour," "consistency," "smell," "taste," and "overall" (mean and SD) of their self-prepared porridges (Days 1 and 8) and of porridges prepared by field assistants (Day 8)

Porridge	*n*	DM content (%) Mean	Bostwick flow rate mm/30 s, 45°C[e] Mean	Colour[d]		Consistency[d]		Smell[d]		Taste[d]		Overall[d]	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Day 1													
Prepared by caregivers													
Group 1	41	20.7	197.2	4.5	0.5	3.3	0.9	4.7	0.5	4.9	0.4	4.7	0.5
Group 2	39	20.4	184.4	4.5	0.6	3.4	0.8	4.8	0.4	4.9	0.3	4.6	0.5
Group 3	38	22.0	198.2	4.4	0.6	3.7	0.9	4.7	0.4	4.8	0.4	4.6	0.6
Group 4	40	22.1	177.4	4.5	0.6	3.6	0.9	4.8	0.5	4.9	0.3	4.6	0.5
Total	158	21.3	189.6	4.5	0.6	3.5	0.9	4.7	0.5	4.9	0.4	4.6	0.5
Day 8													
Prepared by caregivers													
Group 1	40	25.6	159.3	4.5[a]	0.6	4.1[a]	0.8	4.7[a]	0.6	4.9[a]	0.3	4.7[a]	0.5
Group 2	39	23.5	180.1	4.4[a]	0.8	3.8[a]	0.8	4.5[ab]	0.5	4.7[ab]	0.5	4.5[a]	0.6
Group 3	35	26.3	174.6	4.5[a]	0.6	4.1[a]	0.7	4.6[ab]	0.5	4.8[ab]	0.4	4.6[a]	0.5
Group 4	40	24.8	162.9	4.5[a]	0.6	3.9[a]	0.8	4.8[a]	0.4	4.8[ab]	0.4	4.6[a]	0.5
Group 5	41	25.7	165.9	4.3[a]	0.6	3.8[a]	0.8	4.6[ab]	0.5	4.6[b]	0.5	4.4[a]	0.6
Group 6	39	24.8	150.9	4.1[a]	0.8	3.6[a]	0.8	4.3[b]	0.8	4.5[b]	0.7	4.4[a]	0.6
Total	234	25.1	165.2	4.4	0.7	3.9	0.8	4.6	0.6	4.7	0.5	4.5	0.6
Prepared by field assistants[f]													
Porridge 1	208	23–27	160–200	4.5[a]	0.6	4.3[b]	0.6	4.6[a]	0.5	4.8[a]	0.4	4.6[a]	0.5
Porridge 2	30	23–27	>200	4.5[a]	0.6	3.9[a]	0.6	4.7[a]	0.5	4.7[a]	0.5	4.5[a]	0.6
Porridge 3	88	23–27	<160	4.6[a]	0.5	4.3[b]	0.6	4.6[a]	0.6	4.8[a]	0.4	4.6[a]	0.5
Porridge 4	10	27–30	160–200	4.8[a]	0.6	4.5[ab]	0.7	4.8[a]	0.4	4.9[a]	0.3	4.9[a]	0.3
Porridge 5	20	19–23	160–200	4.4[a]	0.7	4.0[ab]	0.8	4.4[a]	0.6	4.7[a]	0.5	4.6[a]	0.5
Overall	356	n/a	n/a	4.5	0.6	4.3	0.6	4.6	0.5	4.8	0.4	4.6	0.5

Note. SC+A: Super Cereal Plus with amylase; SD: standard deviation.

[abc]Values within a column with unlike superscript letters were significantly different ($p < 0.05$).

[d]Evaluated on a five-point scale: 1 (*Very bad*), 2 (*Bad*), 3 (*Neutral*), 4 (*Good*), 5 (*Very good*).

[e]Bostwick flow rate >240 mm/30 s at 45°C were excluded.

[f]Recipes in Table 1.

(FAO/WHO, 2013). Porridge energy density increased from 0.68 kcal/g for SC+ to 1.16 kcal/g for SC+A when prepared by field assistants (Kampstra et al., 2017). In our study in Rwanda, caregivers prepared SC+A porridges with a similar energy density (1.0 kcal/g).

Due to the different inclusion criteria and Study Groups, random selection of the study population was not feasible, which may have resulted in self-selection bias (Gibson, 2005). Although some firewood users at the household were asked to use charcoal at the study site, compliance was high in the study and there were no dropouts after consent forms were signed (0%).

No difference in porridge DM content nor in Bostwick flow rate was found between the firewood and charcoal groups after 1 week of practice, and no negative experiences related to the porridge preparation time were shared during the interviews and FGDs. Nearly all caregivers brought the porridge to a rolling boil, which has been documented to be "sufficient to inactivate pathogenic bacteria, viruses and protozoa" (World Health Organization, 2015). In line with recommendations to minimize micronutrient losses for selected vitamins (e.g., vitamins C and E; Rowe, Ogden, Pike, Steele, & Dunn, 2009) and with the SC+A preparation instructions, porridges were not boiled for a very long time (e.g., >20 min). Nevertheless, not all caregivers practiced the recommended 5 min of porridge boiling, which suggests that it is important to better emphasize the need for a boiling time of 5 min.

The median amount of flour used (g) on both Days 1 and 8 show that approximately one porridge can be prepared each day for 1 week from a 1.5-kg bag SC+A, which was in line with the median eight porridges prepared at home. The amount of porridge prepared (g) on Day 1 (896.1 ± 356.9) and Day 8 (837.6 ± 277.9) was higher than the assumed gastric capacity of 249 g/meal at 6–8 months, 285 g/meal at 9–11 months, and 345g/meal at 12–23 months (Dewey & Brown, 2003). This suggests that the porridge is also prepared to feed other household members, because there is enough; or because it is difficult to prepare smaller amounts, for example, due to pot size; or because cooking fuel limitations restrict the number of different foods that can be prepared for one meal time. That larger amounts were prepared was in line with within household porridge sharing as reported in interviews and FGDs. To ensure that targeted individuals consume the intended quantity of SC+A porridge, communication on the importance of SC+ porridge preparation for and consumption by the intended target population needs to be strengthened.

The "overall" SC+A porridge acceptability score was approximately 1 point higher amongst Rwandan caregivers of children 6–23 months (total mean 4.5–4.6) in this study as compared with the study that had been conducted in Burkina Faso (mean 3.3–3.6; Kampstra et al., 2017). This might be due to differences in taste or porridge thickness preferences between different regions (personal communication, C. Mouquet-Rivier) or different tendency for scoring on the hedonic scale.

Both the quantitative and qualitative findings indicate that porridges prepared using SC+A were well accepted, and some caregivers mentioned that it was even better than the regular SC+ porridge. This could be related to the higher porridge DM and lower water content and hence the taste of the ingredients such as milk (8%) and sugar (9%) being stronger.

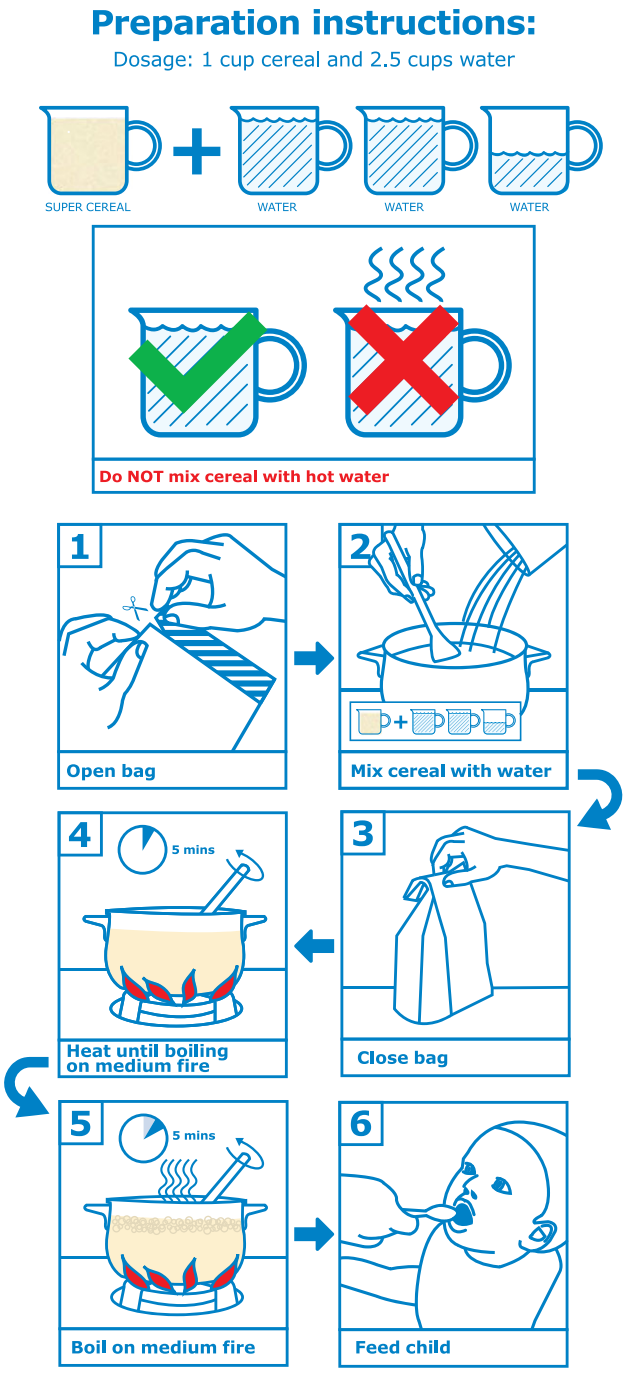

FIGURE 2 Final preparation instructions for SC+A

Furthermore, sensory evaluation of the porridges prepared by field assistants suggested that porridge DM content (19–23%, 23–27%, 27–30%) did not influence sensory acceptability scores on any of the five different sensory categories (colour, consistency, smell, taste, and overall). Due to limited tools available to control porridge warming time, the set criteria for Porridge 4 (DM of 27–30%) and 5 (DM of 19–23%), both with a Bostwick flow rate of 160–200 mm/30 s at 45°C, were less frequently met as compared with Porridges 1, 2, and 3. Only limited data were therefore available on the porridge acceptability of Porridges 4 and 5, and hence a lack of power may have caused the absence of a significant difference in acceptability of porridges with different DM content. Caregivers preferred porridges with a Bostwick flow rate of ≤200 (i.e., thicker) over porridges of >200 mm/30 s at 45°C (i.e., thinner).

5 | CONCLUSION

This study showed that Rwandan caregivers prepared a 25% DM content SC+A porridge that meets the recommended food energy density by the WHO (2012) and the CAC (FAO/WHO, 2006; FAO/WHO, 2013) after a week of practice. This was achieved by the distribution of SC+A, with revised preparation instructions and sensitisation messages, but without additional cooking training or demonstrations. The new preparation instructions were well understood by caregivers, and the overall acceptability of porridges prepared was very good. In conclusion, the feasibility of increasing porridge energy and nutrient density when adding amylase to SC+ flour and providing adjusted preparation instructions, to meet the recommended food energy density of at least 0.8 kcal/g for young children, is confirmed. Therefore, SC+ food specifications can be adjusted to include amylase (SC+A) and to allow the preparation of a 25% DM content porridge with an energy density of 1.0 kcal/g. In addition, the recommended preparation instructions for SC+A were revised, including an adjusted flour: water ratio of 1:2.5 based on the feedback from caregivers in Rwanda and in Sierra Leone (July, 2016; data not shown; Figure 2). Global distribution of SC+A should be accompanied by strong communication on product purpose and target population whilst emphasizing the preparation instructions, including flour:water ratio of 1:2.5, mixing of flour and water before cooking, and the importance of a 5-min boiling time to ensure food safety.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

BB, SP, VHN, and SdP designed the research; BB, SS, JN, and EG conducted the research; BB and SS analysed the data; BB, SS, VHN, and SdP wrote the paper; BB and SdP had primary responsibility for final content; all authors have read and approved the article.

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