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Nutritional and Sanitary Quality of Infant Flours Produced in Ouagadougou, Burkina Faso

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Abstract

The quality of infant flours used during the weaning age is of great importance in that it conditions the nutritional health of infants and young children. This study aimed to assess the nutritional and sanitary quality of infant flours produced in the city of Ouagadougou. This was a cross-sectional study including 11 out of 25 infant flour production units that gave their consent to partake in the study. In total, 25 infant flour samples have been collected from July to September 2021. The physicochemical and microbiological parameters were determined according to standard methods. The ANOVA analysis of variance showed significant differences between the means of the physico-chemical and the means of the microbiological parameters respectively. The results showed that 60% of proteins and 80% of lipid and total carbohydrate contents were below the authorised limits. The energy values were below the authorised limit in 88% of the cases. All instant infant flours had microbiological loads compliant with Burkinabè standards. As for infant flour to be cooked, 63.64% and 81.82% had satisfactory numbers of total coliforms and faecal coliforms respectively. *Staphylococcus aureus* and *Escherichia coli* were detected in these samples with 86.36% of infant formulae having results below the recommended limit. These results show that the infant flours produced in Ouagadougou were somehow of acceptable quality. However, there is a need to improve the formulae for macronutrient contents, energy values and sanitary quality to comply with the recommendations.

Keywords

Nutritional and Sanitary Quality, Infant Flours, Ouagadougou, Burkina Faso

1. Introduction

Infant flour is a complementary food designed to meet the nutritional needs of infants and young children, taking into account the intake of breast milk and the daily frequency of meals [1]. From the age of six months, it is essential to supplement the intake of breast milk with a diversified and high nutritional density so-called "complementary" diet to meet the needs of infants and young children [2] [3]. Feeding infants and young children is critical because during this period they have a high demand for nutrients. Inadequate nutrition during this period could have irreversible consequences on infant and young child growth, cognitive development, morbidity, and mortality throughout life. Indeed, productivity is reduced, affecting a country's economic development [4]. In Burkina Faso, the national nutritional survey of 2021 revealed that the prevalence of acute malnutrition was 9.7% for weight-for-height index including 0.8% of the severe form, 21.6% for stunting with 6% of the severe form and 17.5% for underweight including 3.4% of the severe form [5]. These results indicate that the nutritional status of children under five is still of concern. Malnutrition therefore constitutes a public health problem as it is the underlying cause of 35% of deaths in children under five [5]. More than a third of deaths of children under five are directly or indirectly attributable to malnutrition [6]. In recent years, Burkina Faso has faced health (COVID-19) and security challenges that have accentuated this worrying situation. It is therefore more than necessary to provide children with good-quality flour to reduce malnutrition. An infant flour must meet both good nutritional and sanitary quality to be adequate for the consumption of infants and young children [7].

This study assessed the nutritional and sanitary quality of infant flours produced in Ouagadougou (Burkina Faso). More specifically, it involved determining the physicochemical characteristics of the infant flours produced, then comparing the nutritional and the hygienic quality value of these infant flours on the basis of the FAO/WHO Codex standard and the Burkinabè standard (NBF 01-198.2014), and finally, assessing the microbiological quality of these infant flours. To do this, a cross-sectional study was conducted among 11 out of 25 production units in Ouagadougou contacted and willing to partake in the study. The results of this study will allow us to update the data on the nutritional and sanitary quality of infant flour produced locally and to recommend the improvement of the formulae for the well-being of this vulnerable group.

2. Material and Methods

2.1. Study Design, Site and Infant Flour Collection Period

This was a cross-sectional study including all the infant flour production units

identified in the city of Ouagadougou. A total of 25 production units have been identified and an investigation was conducted using a pre-tested, structured questionnaire. This involved collecting information from each infant flour production unit about the raw materials used, the sources of supply of these raw materials, the preservation methods used and the production, packaging and storage processes of infant flour. Information on the production frequency, the type of flour produced, the targeted audience, the micronutrients used for the enrichment of infant flour, the status of quality monitoring (Physicochemical, microbiological and toxicological) and the consent to partake in the study have also been collected. The different infant flours used for this study were collected from 11 infant flour production units that gave their consent (Figure 1). The samples were collected from July to September 2021. In total, 25 infant flour samples have been collected. Most infant flours were packaged in 500 g packages. For each sample, 500 g was taken. The samples were selected on the basis of a survey of the production units which have identified the different raw materials used.

Exclusion criteria: Excluded from the study were any production unit that had not given its consent to participate in the survey; any production unit that had participated in the survey but had not given its consent to furnish samples of the infant flour produced.

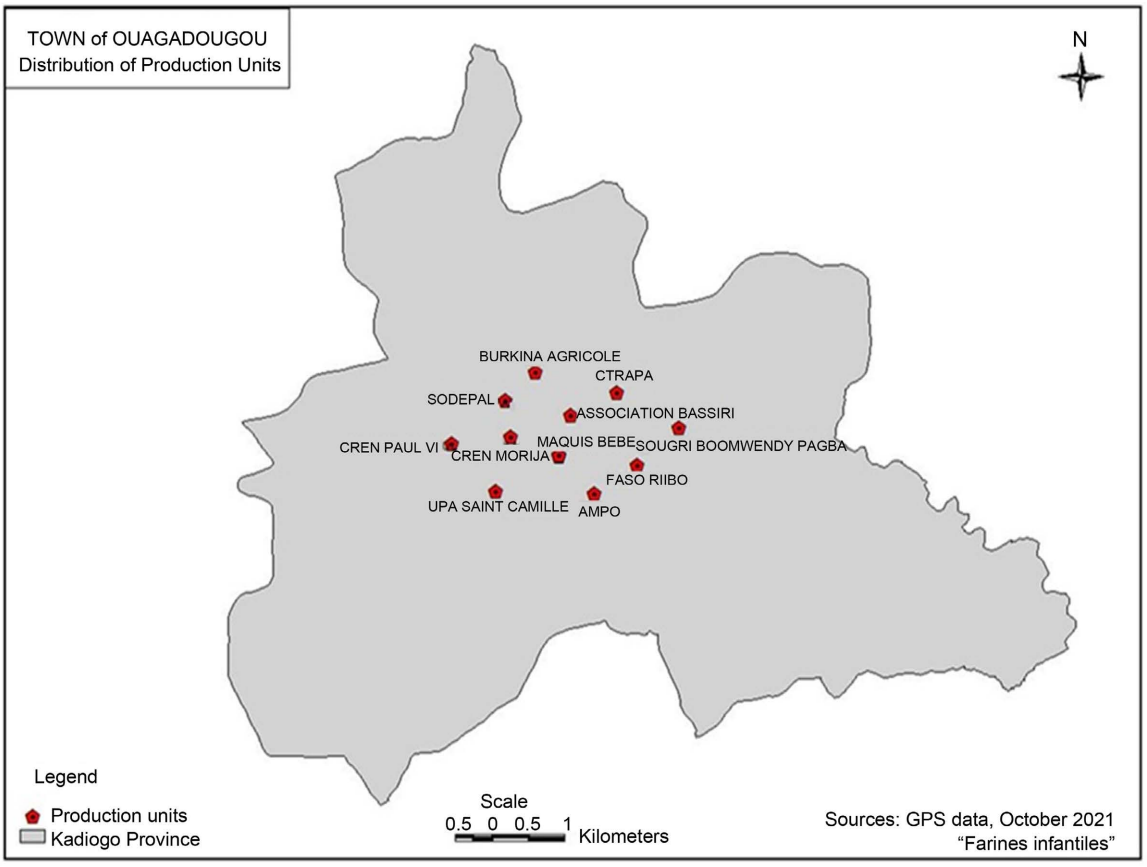

Figure 1. Collection sites of infant flour samples.

2.2. Analysis of the Physicochemical and Nutritional Parameters of Infant Flour

The water content was determined according to the AOAC 925.10 thermogravimetric method [8].

Briefly, 5 g of each infant flour sample was weighed using an analytical balance (Ohaus, Switzerland) and placed in clean, dry aluminum crucibles. The whole was placed in an oven at 105˚C for 4 hours. The aluminum crucibles were then removed, cooled in a desiccator for 30 minutes, and then weighed. The operation was repeated until a constant mass was obtained. The water content was then determined according to the formula:

$$\text{Water content}(\%) = \left(PE - \left(MF - M0\right)/PE\right) \times 100$$

PE: test portion (g);

*M*0: empty mass of the crucibles (g);

MF: final mass (crucible + dry matter) after passage in the oven (g).

The ash content was determined according to AOAC official method 923.03 [9].

For this, 2 g of each sample of infant flours were weighed in porcelain crucibles. The whole was placed in a muffle furnace (Barnstead/Thermolyne, USA) at a temperature of 550˚C for 4 hours, after which the crucibles were removed, and re-cooled in a desiccator for 30 minutes before being weighed using an analytical balance (Sartorius, France). The ashes obtained were again placed in the furnace for 1 hour and re-weighed after cooling in a desiccator for 30 minutes. The cooling operation was repeated until a constant value was obtained. The percentage of total ash was calculated according to the following relationship:

$$\text{Ash content}(\%) = \left(\left(MF - M0\right)/PE\right) \times 100$$

PE: test portion (g);

*M*0: empty mass of the crucibles (g);

MF: final mass (crucible + dry matter) after passage in the oven (g).

The total protein was determined by the Kjeldhal AOAC 979.09 reference method [9].

Briefly, 0.2 g of each infant flour sample was placed in clean and dried Kjeldahl matras. To each test sample, 5 g of Kjeltabs ck tablet and 10 mL of sulfuric acid were added. The mixture was mineralized at 400˚C for 4 hours. After mineralization, 20 mL of distilled water and a few drops of phenolphthalein were added. Then, the contents of the matras were distilled in a Kjeldahl distiller (Foss, Sweden) and then 60 mL of 10N sodium hydroxide were introduced automatically during distillation. The distillate was collected in 20 mL of an aqueous solution of boric acid of concentration 40 g/L and a few drops of helianthin and bromocresol green. Distillation was stopped when the volume of the distillate reached 150 mL. The distillate containing the proteins in the ammonium form was titrated with a 0.1N hydrochloric acid solution. The titration was stopped after obtaining a pink color. The total protein content was calculated by

the following formula:

$$\text{Total protein}(\%) = \left(\left((Ve - Vb) * 0.014 * 0.1 * 6.25\right) / PE\right) \times 100$$

Vb = volume of hydrochloric acid (0.1N) required to neutralize the blank (mL);

Ve = volume of hydrochloric acid (0.1N) required to neutralize the sample (mL);

0.1 = Normality of the sulfuric acid solution;

PE = test portion (g);

0.014 = Molar mass of nitrogen × 10^{-3};

6.25 = conversion factor.

The lipid content was determined according to the Soxhlet AOAC 960.39C method [9].

Briefly, 5 g of infant flour were placed in an extraction cartridge, plugged with cotton wool and placed in a 150 mL Soxhlet flask (Lenz, Germany). The Soxhlet flask was mounted on a 500 mL flask (Lenz, Germany) containing approximately 250 mL of petroleum ether. The extraction was carried out for 6 h. At the end, the extract was recovered and the solvent separated from the fat by evaporation under reduced pressure in a rotavapor (Büchl; Germany). The flasks containing fat were placed in an oven at 35˚C for 30 minutes and weighed after cooling. The evaporation operation in the oven (Memmert; Germany) was repeated until a constant mass was obtained. The total fat content was determined according to the relationship:

$$\text{Lipid content}(\%) = \left((MF - M0) / PE\right) \times 100$$

M0: mass of the empty balloon (g);

MF: mass of the balloon containing the lipids (g);

PE: Test portion (g).

The carbohydrate content was determined using the differential method described by Barminas *et al.* [10].

The carbohydrate content was calculated relative to the dry matter according to the following formula:

$$\text{Carbohydrate content}(\%) = 100 - \%(\text{proteins} + \text{lipids} + \text{ashes})$$

To determine the theoretical energy value, the sum of the products of the major constituents (carbohydrates, proteins, lipids) was made with their thermal coefficients defined by Atwater and Bénédict [11] according to the formula:

$$\text{Energy value}(\text{Kcal}/100\,\text{g}) = \%\text{Protein} \times 4\ \text{Kcal} + \%\text{Glucids} \times 4\ \text{Kcal} + \%\text{Lipid} \times 9\ \text{Kcal}$$

2.3. Evaluation of the Microbiological Quality of Infant Flour

The physiological solution that was used is the sodium chloride solution (NaCl) 9‰. This solution was sterilized in the autoclave at 121˚C for 15 minutes after being distributed in different bottles. For the preparation of the stock solution,

10 g of infant flour were mixed in 90 mL of sterile physiological water. The solution obtained was left to stand for 45 minutes to allow the germs to revive at room temperature. The solution was then homogenised for two minutes in the stomacher and the stock solution corresponding to the 10^{-1} dilution was obtained. From this suspension, a series of decimal dilutions was carried out until the 10^{-6} dilution was obtained. For the preparation of the stock solution used for the detection of salmonella, 25 g of infant flour were mixed with 75 mL of water and the different dilutions were obtained as described above. The preparation of the culture media consisted of diluting the corresponding mass of each lyophilised medium with 1 L of distilled water and placing the solutions in a boiling water bath for complete dissolution. The solutions were then sterilised in an autoclave at 121˚C for 15 minutes except for the Violet Red Bile Lactose (VRBL) and Salmonella/Shigella (SS) solutions and then cooled to 50˚C. Then, 20 mL of the solution was poured into sterile Petri dishes. Total and thermotolerant (fecal) coliforms were counted on VRBL agar; Sabouraud Chloramphenicol (CAF) agar was used for the count of yeasts and moulds. Salmonella/Shigella (SS-agar) and Xylose Lysine Deoxycholate (XLD) medium were used for the search for Salmonella; Eosin Methylene Blue (EMB) medium was used for the enumeration of Escherichia coli; Baird Parker medium with egg yolk and potassium tellurite was used for the enumeration of Staphylococcus aureus; and finally, Plate Count Agar (PCA) medium was used for the inoculation of Total Mesophilic Aerobic Flora (TMAF). For inoculation, the mass inoculation method was used. To do this, 1 mL of each decimal dilution selected was taken aseptically and introduced into a sterile Petri dish, 15 mL of sterilized culture medium was added and the whole was homogenised by rotating the covered Petri dishes. The dishes were left to solidify (10 min) at room temperature before being incubated in an oven, at the temperatures and durations required for each microorganism sought. The Petri dishes inoculated for the enumeration of total mesophilic aerobic flora were incubated at 30˚C for 72 hours ±3 hours. And the Petri dishes for the enumeration of yeasts and moulds were incubated at 25˚C for 5 days and those for *Escherichia coli* were incubated at 44˚C for 24 hours ± 2 hours. For the enumeration of coliforms, the Petri dishes were incubated at 37˚C for total coliforms and at 44˚C for thermotolerant coliforms, for 24 hours ± 2 hours. For the enumeration of *Staphylococcus aureus*, the incubation was done at 37˚C for 48 hours and finally, for the enumeration of Salmonella, the incubation was done at 37˚C for 24 hours.

The total mesophilic aerobic flora (TMAF) was counted according to the Burkinabè standard NBF 01-122: 2009 [12]. Total and thermo-tolerant coliforms were estimated according to the standard NF V 08-060: 2009 [13]. The standard NBF 01-122: 2009 [12] was used to enumerate yeast and moulds. The enumeration of staphylococci was done according to the international standard ISO 6888-1: 2021 [14]. The calculation of Escherichia coli was done in the different samples following the standard NF ISO 7251:2005 [15]. The search for Salmonella spp. was carried out in stages according to the international standard NF

ISO 6579-1: 2017 [16].

2.4. Interpretation of Microbiological Results

The results of the count of TMAF, total and thermotolerant coliforms, yeast and moulds, Escherichia coli and Staphylococci were interpreted according to a two-class plan; satisfactory when the results were below the standards and unsatisfactory when these were above or equal to the standards. Similarly, those of Salmonella were interpreted according to a two-class plan: absence in 25 g (when the result was good and the flour deemed satisfactory) or presence in 25 g (when the result was not good and the flour declared unfit for human consumption).

3. Statistical Analysis

The data was entered into Excel 2016 software.

The calculation of the means and standard deviations of the various physicochemical and microbiological parameters carried out in triplicate was done with the "mean" and "standard deviation" functions of the Excel 2016 software. The ANOVA analysis of variance was used to test the significant differences between the means of the physicochemical parameters and between the means of the microbiological parameters respectively from the different production units. For $p < 0.05$, the difference was considered significant.

4. Results and Discussion

4.1. Physico-Chemical and Nutritional Parameters of Infant Flour

Table 1 presents the results of the various physicochemical and nutritional parameters of the infant flour samples, in particular, water and ash, the proteins, lipids, and carbohydrates contents (expressed in grams per hundred grams of dry matter (g/100g dry matter)). It also presents the energy values of these infant flour samples expressed in kilocalories per hundred grams of dry matter (Kcal/100g DM).

Water content: The results revealed that 80% of the infant flour samples had a water content below the 8% threshold set by Fasonorm [17]. The water content of infant flours was not different from one sampling area to another ($p = 0.291$). The low humidity could be explained by the use in the production process of infant flours, of techniques such as roasting or cooking-extrusion of raw materials, which leads to a loss of water [18]. This water loss increases the shelf life of infant flours [19]. Conversely, 20% of infant flour assessed had water content exceeding the 8% set by Fasonorm. The high-water content in infant flour increases the risk of moulds and bacterial growth. It reduces storage time [20], negatively affecting the quality of infant flour and causing diseases in infants.

Ash content: From the 25 infant flour samples assessed, 24 (96%) had an ash content in accordance with the recommendations of the Codex Alimentarius

(*i.e.* ≤ 3%). The values were between 0.24% and 3.54%. Studies have reported contents between 1.18% and 3.30% [17]. This disparity in values could be due to the fact that some production units have the possibility of incorporating Mineral and Vitamin Supplements (MVS) into infant flours. In contrast, others have difficulties in acquiring these MVS [21]. It is in fact difficult for small production units to obtain supplies in MVS from international groups especially when it is ordered in small quantities. To overcome these problems, centralising the MVS orders through an appropriate structure and tax exemption would be an extremely welcome boost to promote the effective fortification and affordable cost of infant flours produced. In addition, the mineral contents in these infant flours can be optimised by using locally produced foods such as pumpkin, red beans, and sweet potato with orange flesh [22] [23].

Protein content: In total, 60% of infant flours had a protein content below the threshold of 12.7% set by Fasonorm (NBF 01-198.2014) [24]. According to ABNORM, African infant flours made of mixtures of cereals and legumes have protein levels below the recommended standards [24]. Frequent consumption of infant flours with a low protein content could lead to severe long-term malnutrition in infants and young children [25] [26]. To remedy this, it is advisable to increase the protein content in infant flour by adding local ingredients rich in protein (dried fish, soybeans, peanuts, etc.) [26] [27]. The present study revealed that infant flours such as FMMRJ, MSL, NTV, BAM, SL, CRL and PGMa presented protein contents higher than Burkinabè standard NBF 01-198.2014 [28]. Bruce and Kayode found similar results for infant flours produced in Benin that had protein content between 19% and 24% [28]. The use of soy which contains 38% - 40% of protein according to Soro *et al.* [29] could be one of the reasons for this high protein content in infant formulas. Soy availability and lower cost compared to proteins of animal origin justifies its wide use in children's diets [29].

The animal protein proportions of 6% recommended by the WHO were not respected in all the infant flours in the present study. This explains the addition of milk or dried fish powder when preparing flours-based porridges specially produced in the CRENs to increase the animal protein content. However, a very high amount of proteins can lead to kidney overload and also reduce appetite in children [30].

Lipid content: According to Fasonorm standards, the lipid content in infant flour must be > 8.5% [17]. The results of this study indicated that 80% of the infant flours analysed had lipid content below the threshold recommended by Fasonorm. Very often, complementary foods in Africa are not only low in lipids and essential fatty acids but also deficient in polyunsaturated fatty acids [31]. The low lipid content in infant formulas could be explained by the desire of infant formula producers to ensure long shelf life, as fats are prone to rancidity, especially when they are rich in unsaturated fatty acids. According to Olive *et al* [21], studies conducted by the French National Research Institute for Sustainable Development (IRD) and the Group for Research and Technology Exchanges

(GRET) showed that infant flours produced locally had a lipid content lower than the recommended standards.

Total carbohydrate content: The total carbohydrate contents were statistically different between infant flours produced ($p < 0.001$). According to the Codex recommendation (CAC/GL08-1991) for infant flours, the total carbohydrate content should be 64 ± 4 g/100g dry matter. It appears that 92% of infant flours of the present study had a carbohydrate content greater than or equal to the standard. This result is in accordance with this of Nago *et al*. who reported that the main source of carbohydrates of the African diet is based on cereals [32]. The carbohydrate content of flours intended for young children is attributable to their cereal composition (pearl millet, maize, rice) [33].

Theoretical energy value: According to Fasonorm's recommendations, the energy value of infant flours must be greater than 420 Kcal/100g [17]. The theoretical energy value of infant flours in the present study was between 356.34 Kcal/100g and 454.9 Kcal/100g of dry matter. There was a statistically significant difference between producers' samples ($p < 0.001$). We had 12% of infant flours with a theoretical energy value in line with the standard against 88% which had a lower value than the Fasonorm recommendation. Our results are similar to those reported by Sanou *et al*. in Burkina Faso who found that 12.5% of infant flours had energy value in line with the standard of Fasonorm [17]. The energy value of the infant flours in our study was in the vast majority lower than the standard. However, these infant flours produced in Burkina Faso constitute a more important source of energy for children compared to the traditional *ben-saalga* porridge, which is very low in energy (30 Kcal/100g of porridge) [33] and yet most often given to infant and young children as a complementary food in Burkina Faso. The infant flours that are the subject of this study are therefore more recommended than the traditional *ben-saalga* porridge.

The enrichment of infant flours with food and ingredients such as dried fish powder, soumbala, milk, moringa, sweet potato with orange flesh, monkey bread, pumpkin, etc., the use of sources of amylases, as well as the use of production processes such as germination should be promoted to improve further the energy value of infant flours produced at the national level.

4.2. Microbiological Analysis of Infant Flour

1) Microbiological analysis of instant infant flours

Table 2 shows the number of colonies formed by the microorganisms in the different samples of instant infant flours expressed in CFU/g. The microorganisms concerned were Total Mesophilic Aerobic Flora, Total Coliforms, Thermo-tolerant Coliforms, Yeast and Moulds, *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella spp*.

The microbiological analyses of the instant infant flours revealed that they all had microbiological loads complying with the Burkinabè standards [12]. Yeast and moulds were identified in a sample of an instant infant flour out of the three collected. For the Total Mesophilic Aerobic Flora (TMAF), the analysis of the

Table 1. Physico-chemical and nutritional characteristics of infant flour.

Codes infant flour samples	Ashes	Water	Proteins	Lipids	Carbohydrates	Energetic value
FMi.MRJ	1.35 ± 0.03	4.82 ± 0.01	14.22 ± 0.01	5.78 ± 0.15	73.83 ± 0.2	404.21 ± 0.56
Fri MRJ	0.24 ± 0.04	8.38 ± 0.05	12.41 ± 0.68	0.22 ± 0	78.74 ± 0.59	366.58 ± 0.36
FMMRJ	2.2 ± 0.1	7.98 ± 0.23	23.71 ± 0.01	1.63 ± 0.15	64.48 ± 0.03	367.42 ± 1.3
FS.MRJ	1.29 ± 0.01	2.75 ± 0.08	12.81 ± 0.33	7.81 ± 0.29	75.33 ± 0.55	422.9 ± 1.75
MSL	2.68 ± 0	4.88 ± 0.02	21.61 ± 0.01	17.03 ± 0.3	53.8 ± 0.32	454.9 ± 1.4
NTV	2.83 ± 0.07	5.52 ± 0.08	17.59 ± 0.65	8.89 ± 0	65.18 ± 0.66	411.08 ± 0.01
VCS.Inst	1.23 ± 0.07	5.57 ± 0.07	9.49 ± 0.33	2.97 ± 0.3	80.74 ± 0.17	387.62 ± 2.06
VCS.Lc	1.8 ± 0.04	3.32 ± 0.01	11.97 ± 0.32	3.93 ± 0	78.97 ± 0.29	399.15 ± 0.12
VTL.Inst	1.19 ± 0	4.82 ± 0.18	10.34 ± 0.33	3.47 ± 0.15	80.18 ± 0.29	393.29 ± 1.48
VTL.Lc	1.2 ± 0	4.68 ± 0.06	12.61 ± 0.33	6.5 ± 0.3	75.01 ± 0.56	409 ± 1.75
KSN+	2.05 ± 0.04	5.52 ± 0.13	10.64 ± 0	7.41 ± 0	74.38 ± 0.08	406.78 ± 0.35
BAM	2.86 ± 0.08	6.57 ± 0.13	19.66 ± 0.01	15.63 ± 0	55.28 ± 0.05	440.39 ± 0.23
SL	2.62 ± 0.12	5.19 ± 0.03	18.44 ± 0.63	9.91 ± 0.3	63.83 ± 0.42	418.31 ± 1.84
FRI6	0.42 ± 0	9.42 ± 0.04	10.13 ± 0.69	0.11 ± 0.16	79.91 ± 0.57	361.17 ± 0.93
FMI6	2.43 ± 0.01	6.85 ± 0.07	10.33 ± 0	2.79 ± 0	77.6 ± 0.06	376.83 ± 0.22
FSO6	1.82 ± 0.12	7.63 ± 0.19	12.53 ± 0.34	2.16 ± 0	75.86 ± 0.27	373.01 ± 0.29
Fma6	0.51 ± 0.04	7.63 ± 0.22	10.17 ± 0.34	0.97 ± 0.15	80.71 ± 0.31	372.3 ± 1.5
FTZ	2.3 ± 0.09	4.98 ± 0	14.96 ± 0.33	4 ± 0	73.76 ± 0.24	390.87 ± 0.36
CRL	2.56 ± 0.06	5.07 ± 0.15	19.33 ± 0.01	8.32 ± 0.15	64.72 ± 0.36	411.09 ± 0.06
PGMa	2.76 ± 0.2	6.65 ± 0.07	18.5 ± 0.35	9.75 ± 0.15	62.34 ± 0.77	411.08 ± 0.33
BRPE1	1.6 ± 0.03	10.66 ± 0.02	11.26 ± 0	2.8 ± 0.16	73.67 ± 0.16	364.93 ± 0.77
BRPE2	1.96 ± 0.04	7.07 ± 0.02	12.47 ± 0.33	6.99 ± 0.15	71.51 ± 0.16	398.86 ± 0.68
BRPE3	1.78 ± 0.03	7.68 ± 0.26	12.55 ± 0.34	7.58 ± 0	70.41 ± 0.63	400.06 ± 1.14
BRPE4	3.54 ± 0.03	10.34 ± 0.03	10.97 ± 0.34	2.45 ± 0.32	72.7 ± 0.6	356.74 ± 1.79
Fri	0.31 ± 0.03	8.62 ± 0.03	10.53 ± 0	0.22 ± 0	80.31 ± 0.05	365.34 ± 0.23
Codex Stan 74-1981	≤3			10 - 25	64 ± 4	≥400
NBF 01-198.2014		≤8	>12.7	>8.5		≥420
Conformity	96%	80%	40%	20%	20%	12%
Non-conformity	4%	20%	60%	80%	80%	88%

samples showed a load below the norm (<10^4 CFU/g). Total Coliforms, Thermo-tolerant (faecal) Coliforms, *Staphylococcus aureus*, *Escherichia coli* and Salmonella were not identified in the instant infant flour samples assessed. These satisfactory results corroborate those reported by Waré *et al*. in a study previously carried out in Ouagadougou [34].

These results in line with the standards could be explained by the cooking techniques used in the processes of these instant infant flours. Extrusion cooking allows a considerable reduction in the microbial load due to the very high temperatures used [21]. Also, the appropriate type of packaging protects infant flours and preserves them from poor storage conditions. This guarantee good health quality of infant flours.

Table 2. Microbiological characteristics of instant infant flours.

Samples	TMAF	TC	ThC	Staph	YM	*E. coli*	Sal. in 25 g
SL	$1.64 \times 10^2 \pm 0.13 \times 10^2$	ND	ND	ND	ND	ND	Absence
VTL.inst	$7.82 \times 10^2 \pm 0.06 \times 10^2$	ND	ND	ND	ND	ND	Absence
VCS.inst	$3.09 \times 10^2 \pm 0.26 \times 10^2$	ND	ND	ND	$9.09 \times 10^1 \pm 0.22 \times 10^1$	ND	Absence
Mean (UFC/g)	4.18×10^2	ND	ND	ND	3.03×10^1	ND	Absence
Standards	**$<10^4$ CFU/g**	**$<2 \times 10^1$ CFU/g**	**$<2 \times 10^1$ CFU/g**	**<10 CFU/g**	**-**	**<2 CFU/g**	**Absence**
Conformity	100%	100%	100%	100%	-	100%	100%
Non-conformity	0%	0%	0%	0%		0%	0%

TMAF: Total Mesophilic Aerobic Flora; TC: Total Coliforms; ThC: Thermo-tolerant Coliforms; YM: Yeast & Moulds; Staph: Staphylococcus aureus *E. coli*: Escherichia coli; Sal: Salmonella; CFU/g: Colony Forming Unit per gram, ND: Non Detected.

2) Microbiological analysis of infant flours to be cooked

Table 3 shows the number of colonies formed by the TMAF, Total Coliforms, Thermo-tolerant Coliforms, Yeast and Moulds, *Staphylococcus aureus*, *Escherichia coli*, and Salmonella, in the different infant flour samples to be cooked.

The load in TMAF of infant flours varied between $2.09 \times 10^2 \pm 0.19 \times 10^2$ CFU/g and $2.93 \times 10^6 \pm 0.19 \times 10^6$ CFU/g. Most infant flours to be cooked had a TMAF content lower than the recommended limit. Around 82% (81.82%) of the samples had a microbial load below the limit recommended by Fasonorm [17] compared to 18.18% of these flours presenting values above the limit of this standard. According to studies conducted by Bougma *et al.* in Ouagadougou, all infant flours had a TMAF below the limit set by the Burkinabè standard [35]. An acceptable TMAF in infant flours indicates the absence of spoilage and good microbiological quality for infants and young children who are the most consumers [35]. The microbial load in total and thermo-tolerant coliforms varied respectively between $2.00 \times 10^1 \pm 0.129 \times 10^1$ UFC/g and $1.52 \times 10^3 \pm 0.71 \times 10^3$ UFC/g then 5.45 ± 0.39 UFC/g and $3.45 \times 10^2 \pm 0.13 \times 10^2$. Respectively, 63.64% and 81.82% of infant flour samples had total and thermo-tolerant coliform values below the limit thresholds recommended by Fasonorm. These results are similar to those of Sanou *et al.* and Waré *et al.* whose studies found coliform loads in some of the infant flours produced in Ouagadougou and some towns in Burkina Faso above the standards [17] [34]. Coliform contamination can occur during

Table 3. Microbiological characteristics of infant flours to be cooked.

Samples	TMAF (CFU/g)	TC (CFU/g)	ThC (CFU/g)	YM (CFU/g)	Staph (CFU/g)	*E. coli* (CFU/g)	Sal in 25 g
FMi6	$1.46 \times 10^3 \pm 0.00 \times 10^3$	$7.27 \times 10^1 \pm 0.13 \times 10^1$	5.45 ± 0.39	$1.09 \times 10^2 \pm 0.51 \times 10^2$	ND	ND	Absence
FMa6	$6.00 \times 10^4 \pm 0.06 \times 10^4$	$1.33 \times 10^3 \pm 0.14 \times 10^3$	$1.29 \times 10^1 \pm 0.77 \times 10^1$	$1.55 \times 10^2 \pm 0.45 \times 10^2$	ND	$1.09 \times 10^1 \pm 0.77 \times 10^1$	Absence
FSo6	$3.82 \times 10^3 \pm 0.42 \times 10^3$	ND	ND	$2.09 \times 10^2 \pm 0.19 \times 10^2$	ND	ND	Absence
FRi6	$2.09 \times 10^4 \pm 0.64 \times 10^4$	$4.27 \times 10^2 \pm 0.12 \times 10^2$	$1.29 \times 10^1 \pm 0.21 \times 10^1$	$1.36 \times 10^2 \pm 0.03 \times 10^2$	$3.64 \times 10^1 \pm 0.26 \times 10^1$	ND	Absence
FS.MRJ	ND	ND	ND	ND	ND	ND	Absence
FH.MRJ	$2.12 \times 10^5 \pm 0.20 \times 10^5$	$1.36 \times 10^2 \pm 0.09 \times 10^2$	$1.82 \times 10^1 \pm 0.64 \times 10^1$	$9.09 \times 10^1 \pm 0.64 \times 10^1$	ND	ND	Absence
Fri.MRJ	$3.25 \times 10^3 \pm 0.03 \times 10^3$	$2.18 \times 10^1 \pm 0.02 \times 10^1$	$1.18 \times 10^1 \pm 0.17 \times 10^1$	$7.27 \times 10^1 \pm 0.13 \times 10^1$	ND	ND	Absence
FMi.MRJ	ND	ND	ND	ND	ND	ND	Absence
VTL.LC	$2.91 \times 10^2 \pm 0.13 \times 10^2$	$2.00 \times 10^1 \pm 0.129 \times 10^1$	8.18 ± 0.64	ND	ND	ND	Absence
VCS.LC	$7.55 \times 10^3 \pm 0.84 \times 10^3$	ND	ND	ND	ND	ND	Absence
MSL	$2.93 \times 10^6 \pm 0.19 \times 10^6$	$4.55 \times 10^1 \pm 3.21 \times 10^1$	ND	ND	ND	ND	Absence
FRi	$2.29 \times 10^3 \pm 0.06 \times 10^3$	$3.64 \times 10^1 \pm 0.26 \times 10^1$	ND	$5.45 \times 10^1 \pm 0.26 \times 10^1$	ND	ND	Absence
PGMa	$1.47 \times 10^4 \pm 0.02 \times 10^4$	$1.36 \times 10^3 \pm 0.02 \times 10^3$	$3.45 \times 10^2 \pm 0.13 \times 10^2$	ND	$7.27 \times 10^1 \pm 0.51 \times 10^1$	ND	Absence
BAM	$4.00 \times 10^4 \pm 0.18 \times 10^4$	ND	ND	$2.82 \times 10^2 \pm 0.26 \times 10^2$	ND	ND	Absence
CRL	$8.64 \times 10^5 \pm 0.26 \times 10^5$	$1.52 \times 10^3 \pm 0.71 \times 10^3$	$1.66 \times 10^2 \pm 0.64 \times 10^2$	$6.36 \times 10^1 \pm 0.19 \times 10^1$	$2.09 \times 10^1 \pm 0.42 \times 10^1$	$4.27 \times 10^1 \pm 0.32$	Absence
NTV	$6.18 \times 10^5 \pm 0.58 \times 10^5$	$1.00 \times 10^3 \pm 0.06 \times 10^3$	$7.27 \times 10^1 \pm 0.13 \times 10^1$	$7.27 \times 10^1 \pm 0.13 \times 10^1$	ND	$4.55 \times 10^1 \pm 0.32 \times 10^1$	Absence
KSN+	$1.76 \times 10^4 \pm 0.01 \times 10^4$	ND	ND	$5.45 \times 10^1 \pm 0.39 \times 10^1$	ND	ND	Absence
BRPE1	$1.36 \times 10^4 \pm 0.95 \times 10^4$	$5.45 \times 10^1 \pm 0.39 \times 10^1$	ND	$3.00 \times 10^2 \pm 0.64 \times 10^2$	ND	ND	Absence
BRPE2	$2.75 \times 10^3 \pm 0.03 \times 10^3$	ND	ND	$2.82.10^2 \pm 0.26.10^2$	ND	ND	Absence

Continued

BRPE3	$1.23 \times 10^4 \pm 0.01 \times 10^4$	$5.55 \times 10^2 \pm 0.03 \times 10^2$	$1.02 \times 10^2 \pm 0.58 \times 10^2$	$2.82 \times 10^2 \pm 0.64 \times 10^2$	ND	ND	Absence
BRPE4	$6.18 \times 10^4 \pm 0.00 \times 10^4$	$1.36 \times 10^2 \pm 0.32 \times 10^2$	$1.00 \times 10^2 \pm 0.06 \times 10^2$	$2.45 \times 10^2 \pm 0.00 \times 10^2$	ND	ND	Absence
FTZ	$2.09 \times 10^2 \pm 0.19 \times 10^2$	ND	ND	ND	ND	ND	Absence
Standards	**$<10^5$ CFU/g**	**$<10^2$ CFU/g**	**$<10^2$ CFU/g**	**$<10^3$ CFU/g**	**<10 CFU/g**	**<10 CFU/g**	**Absence in 25 g**
Conformity	**81.82%**	**63.64%**	**81.82%**	**100%**	**86.36%**	**86.36%**	**100%**
Non-conformity	**18.18%**	**36.36%**	**18.18%**	**0%**	**13.64%**	**13.64%**	**0%**

TMAF: Total Mesophylic Aerobic Flora; TC: Total Coliforms; ThC: Thermo-tolerant Coliforms; YM: Yeast & Moulds; Staph: Staphylococcus aureus; *E. coli*: Escherichia coli; Sal: Salmonella; CFU/g: Colony Forming Unit per gram, ND: Non Detected.

the drying and transformation processes [35]. Good hygienic practices are necessary both during drying and transformation processes which are mostly manual.

The values of yeast and moulds found in infant flours complied with the standards [12]. These results are similar to those of Sika *et al*. [20], but differ from those found by Sanou *et al*. and Waré *et al*. [17] [34] who had found values above the standards in specific infant flour samples. Fungal flora is the cause of taste deterioration. In addition, some moulds are likely to produce toxic substances [36].

Staphylococcus aureus and *Escherichia coli* were determined in infant flour samples at 86.36% below the limit recommended by international standards [14] [15]. Some authors did not identify any colony of *Escherichia coli* nor *Staphylococcus aureus* [17] [37] in former studies on infant flours. *Staphylococcus aureus* is an indicator of risk to consumers [38]. The presence of this microorganism implies contamination of exogenous origin during handling or contact with work equipment [38].

No salmonella has been identified in the infant flour samples during the study. These results corroborate those of Kagambèga *et al*., Sanou *et al*., Ware *et al*. and Sika *et al*. who reported not having also detected Salmonella in the infant flour samples analysed [11] [14] [29] [33].

Salmonella is a microbiological hazard mainly transmissible to humans through food. They are the first microbiological contaminants causing food poisoning [39].

5. Conclusions

The study on the nutritional and sanitary quality of infant flours produced in the city of Ouagadougou in Burkina Faso allowed us to note that nutritionally, the macronutrient contents were acceptable. However, most infant flours had lipid

contents below the limit authorised by the Burkinabè standards. Energy values were below the recommended limit in most infant flours. From a microbiological point of view, all instant infant flours presented microbial loads compliant with the Burkinabè standard NBF 01-198: 2014. Also, most infant flours intended for cooking had total mesophilic aerobic flora, yeast and moulds, and a microbial load of Salmonella that complied with the standards. Nevertheless, infant flours to be cooked were above the recommended limits at 18% for TMAF, 18% to 36% for thermotolerant and total coliforms respectively and around 14% of *Staphylococcus aureus* and *Escherichia coli* respectively.

The infant flours produced at the national level must be further improved to comply with the nutritional and sanitary recommendations. To do so, formulation efforts are still needed to improve the balance of protein sources, fat and micronutrient content in infant flours. Efforts are required to improve the energy density of infant flours and to train producers on good hygiene practices. This study has limitations because some aspects could not be addressed. Further studies are therefore needed to assess the profiles of amino acids, fatty acids, antinutrients and polyphenols in terms of nutritional values of these infant flours. As for the sanitary quality, the assessment of mycotoxin, pesticides and heavy metal contamination in infant flours produced is necessary to ensure the health of this vulnerable consumer group.

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Conflicts of Interest

The authors declare no conflict of interest.

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