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# Effect of germination time on the diastasic power of maize (*Coca-sr variety*) and paddy rice (*Nerica L.56 variety*): Application of amylase rich flours and their extracts in the fluidification and improvement of the energy density of fermented maize gruel

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## ABSTRACT

To proceed this study, corn seeds (Coca-sr variety) and rice (Nerica L.56) were germinated over period of 240 hours. Flours and raw extracts produced were used to prepare fermented maize gruels (17.5% of DM) and the flow rates were evaluated using the Botswick consistometer. We noticed from these analyses that the germinated corn Coca-sr variety, in the form of ARF and its extracts presented an optimum fluidification power at 120 h of germination. As for the ARF of Nerica L.56, an optimum fluidification level was observed for the extract at 168 h contrarily to 72 h for the flour. The use of ARF and extracts from corn (Coca-sr) and rice (Nerica L.56) at 2 % and 2.5 mL resulted in a reduction of their consistency (gruels). Coca-sr ARF at a rate of 2 % fluidifies the gruel of fermented corn hence multipliying the energy density and nutritional value (3.57) more than with its extract and the different forms of the incorporation of rice.

**Keywords:** Germination time, Amylase rich flour, Coca-sr corn, Nerica L.56 paddy rice and flow rate.

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## Introduction

Malnutrition remains a significant and universal public health problem, with a rate of at least 33 % of people affected in at least one of its forms (WHO, 2017). The number of children suffering from acute malnutrition, as well as chronic under-nourished and stunted children, has probably declined over the past decade. However, the still high burden and slow decline on the undernourishment rates are out of step with the sustainable development goals on eradicating infant malnutrition by 2025 (WHO, 2017).

That infant malnutrition which generally appears at weaning age, affects more than one billion people worldwide with 90 % in developing countries (FAO, 2015). Particularly in Cameroon, 33 % of children under-five suffer from chronic malnutrition and more than half of them (18.4%) in severe form (INS 2014). The Far North, North, Adamaoua and East are the most affected regions with 31.6 % ; 23.6 % ; 20.8 % and 25.4 % respectively (INS, 2014). The Western Region being the national pioneer in annual agricultural production in 2014 (128,932 tonnes of cassava, 0.31 million tonnes of maize and 49,963 tonnes of sweet potatoes), is supposed to guarantee the food self-sufficiency of its populations (INS, 2015). Mean while, the INS (2014) reported 4.9 % of malnourished children in that region.

As a remedy, the food industry offers instant flours on the Cameroonian market which are considered by families with low financial incomes as luxurious products (Klang, 2015). To avoid the high economic cost of these supplements, mothers themselves prepare gruels from cereal, tuber and root. However, these products are very rich in starch, whose amylopectin molecules quickly absorb water in a hydrothermal medium to form a boiling starch gel. Cooling this gel to about 45 °C makes the gruel thick, difficult to swallow and especially difficult to digest (Elenga *et al.,* 2012). Since it does not have a viscosity between 1-3 Pa.s or a flow rate between 100-160 mm.30 $s^{-1}$ as recommended by WHO for infants from 6 to 24 months. As a plausible solution, mothers often dilute the gruel after cooking or reduce the dry matter (DM) content to be incorporated: thus reducing its energy density and nutritional values (Zannou-tchoko *et al.,* 2011).

This rheological behaviour of flours locally produced has led to the implementation of common fermentation techniques for the preparation of supplemental gruels. This is the case with the nigerian Ogi and the South African mahewu (Elenga *et al.,* 2012). On the contrary, the cereal fermentation technique does not increase children's energy intake to more than 100 Kcal / 100 mL of gruel (Louembé *et al.,* 2004). However, the reduced stomach capacity (30-40 mL/kg body weight) of infants does not allow them to ingest more than 150-200 mL of gruel in a single meal and the frequency of meals is sufficiently spaced. An effective solution was the depolymerization of starch molecules by the post-cooking incorporation of flours from germinated cereals such as maize (Tambo, 2017). Else, the high germination (depolymerizing) power of rice in the form of paddy has also been demonstrated (Dedi and Allou, 2015). The production conditions of these amylase-rich flours (ARF) are practical and easy to carry out. By the way, Jiang *et al.* (2016), have proven by digital and light imaging techniques that moisture (> 12 %) and duration (0 to 48 h) alone are sufficient in an open environment to generate amylases in the grains and cause the multiplication in the level of α-amylase in the germination nucleus. Tambo (2017), exploited the amylase potential of Acid tolerent population (*Atp*) corn malt (at 120 hours of germination) to improve the flow rate of traditional gruels made from *Atp* corn and retted cassava. Klang (2015), also studied the effect of the form of incorporation of ARF (powder or extract) on the reduction of the consistency of gruels.

However, none of these studies were conducted on the malting duration required to bring the malts to their optimal germination (and/or diastasic) capacity. Varying the malting time of paddy rice (*Nerica L.56* Variety) and maize (*Coca-sr* variety) over a period of 240 hours would then be a suitable way to provide for this measure. The form of incorporation of the ARF would also define the conditions for optimal use of malts.

So, the aim of this study was to determine the malting peaks of these two cereals as well as the conditions of use of their best form of incorporation into gruel made from fermented maize.

## Material and methods

### Plant material

The plant material used for this work consists of white maize (*Coca-sr* and *16625/SR/Cam variety*) and paddy rice (*Nerica L.56* variety ) collected at the IRAD multipurpose station in Dschang, Menoua Department (West Cameroon region). The samples thus collected were sent to the Research Unit of Biochemistry of Medicinal Plants, Food Sciences and Nutrition (RUBPMAN) of the Department of Biochemistry of the University of Dschang where they were used to produce flour and germinated flour. These different flours were used for the different analyses. The choice of maize and rice varieties was made on the basis of their availability and utility.

**Picture 1:** (a): paddy rice seeds *Nerica L.56* variety; (b): corn seeds *Coca-sr* variety.

## Methods of operation

### Production of fermented corn flour and amylase-rich flours

The food matrices from the IRAD station in Dschang were transported to the Research Unit of Biochemistry of Medicinal Plants, Nutrition and Food Sciences (RUBPMAN), for the production of various flours and amylases rich flours.

### Production of fermented corn flour

The transformation of white maize seeds (*16625/SR/Cam* variety) into fermented maize flour was carried out according to the method described by Sanogo *et al.* (1994). Indeed, the sorted and washed seeds were soaked in cold water (22°C) at a corn to water ratio (in kg/l) of 1/5 w/v for 72 hours. After quenching, they were manually despecified, washed and crushed using the ordinary mill. The resulting solution was filtered with a white muslin (150 µm) and the filtrate was left to settle for 24 hours. The paste from the settling process was dried in a "venticell" oven at 45 °C for 48 hours. The dried pulp was ground in the ordinary mill and then sieved (300 µm). The flour obtained was preserved in polystyrene plastic bags and stored in a desiccator before further use for analysis and preparation of the gruels.

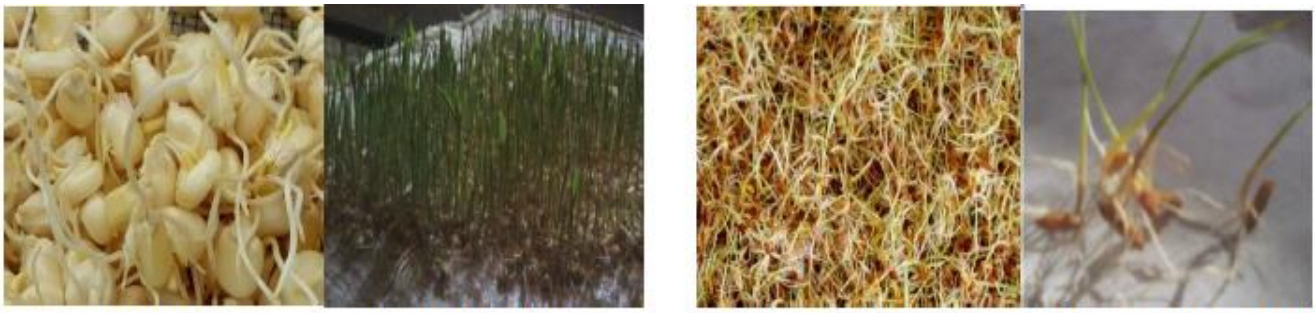
**Picture 2:** (C): fermented Corn paste *16625/SR/Cam variety* ; (d): Corn flour *16625/SR/Cam*

### Chemical and physical characterization of fermented white corn flour

The maize flour produced as described above has been subjected to various analyses. The water content was assessed using the method described by IUPAC (1979). Total lipids were extracted in Soxhlet using the method described by AFNOR (1981). Protein determination was done by the Kjeldahl method (AOAC, 1990), which is based on the transformation of organic nitrogen into ammoniacal nitrogen by mineralization with concentrated sulphuric acid. The protein rate was deduced according to the formula: % protein = %N × conversion factor; Where the conversion factor is equal to 6.25. Fibre content was assessed using the method described by the AOAC (1995). The ash content was determined using the method described by AOAC (1980), which consists of incinerating the sample at 560 °C and in an oxidizing atmosphere until a residue of constant mass was obtained. The method described by AOAC (1980) also made it possible to assess the carbohydrate content. The different ions phosphorus, calcium, potassium, sodium, magnesium and iron were determined by atomic absorption spectroPicturemetry on the ashes from the different samples (AOAC, 1980). The energy value was determined by applying the ATWATER coefficients (Merril and Watt, 1955): 1g of carbohydrate or protein provides 4 Kilocalories, 1g of lipid provides 9 kilocalories. The expression of the energy value is given by the following equation: $Ec = (4\times (\%\ carbohydrate)) + (9 \times (\%\ fat)) + (4 \times (\%\ protein))$. Concerning physical properties, These analyses consisted in determining the mass density according to Okaka *et al.* (1991), and titratable acidity of different flours according to the standard method described by AFNOR (1982).

### Production of germinated corn flour (*Coca-sr*) and paddy rice (*Nerica L.56*)

The transformation of paddy rice and maize seeds into amylase-rich flours (ARF) was carried out according to the method described by Chavane *et al.* (2015), with modification of the sprout which was a covered bowl (with an axial hole for malt aeration) made with bamboo crumb. It has been replaced by a non-absorbent tarpaulin and fully open to the air of the germinating environment. Germination was carried out in a space accessible to daylight, between 18 and 23 °C protected from sunlight. Indeed, the sorted and washed seeds were soaked (1/1.25; w/v) for 24 hours in warm water, then washed and sorted again before being spread on a tarp. The seeds were moistened morning and evening at the interval of 12-hour and this during 240 hours. During germination, seeds were collected every 24 hours, dried, the germ remove manually and the dryed seed was grind with a "Singsung" brand mill and sieved (300 µm). The flours produced were stored in polystyrene plastic bags and stored in a desiccator for later use. The germinating seeds collected every 24 hours were used to produce amylase-rich flours (ARF) and the extracts produced in order to detect the optimal germination time with the best activity not only for the extracts but also for the germinated flour.



*Coca-sr* (120 h) *Coca-sr* (240 h) *Nérica L56* (120 h) *Nérica L56* (240 h)

**Picture 3:** Images of paddy rice *Nerica L.56* and corn *Coca-sr* at 120 h and 240 h of germination.

### Production of amylase raw extracts

Aliquots (2 g) of the germinated flours obtained as described above were introduced into centrifuge tubes. Each weighing was diluted (1/4; w/v) with 8 mL of distilled water and the mixture was homogenized using the vortex for 3 min. The homogenates were centrifuged at 4500 rpm for 15 min and supernatant collected for immediate use (Tambo *et al.,* 2018).

### Influence of germination time on the fluidifying activity of amylase sources

White corn (*Coca-sr*) and paddy rice (*Nerica L.56*) seeds were germinated under the same conditions as earlier seen, for a period of time ranging from 24 h to 240 h. This process resulted in the selection of the best form of incorporation and the best germination time. To proceed, two forms of incorporation of the sources of enzyme were used during the cooking of the gruel to assess the ability of amylases to fluidify the corn gruel. These were the extract (2.5 mL) and small amounts (2 g) of ARF. Indeed, 100 mL of distilled water was added to 20.176 g of corn flour (17.5 g of DM) as well as to the other flour masses. Each beaker containing the flour-water mixture was heated to 40 °C in a water bath, the temperature of which was previously programmed at 99 °C. The gruels were stirred from time to time until the temperature of 95 °C in the core of the product was reached. Then, maintained for 10 minutes at this temperature to ensure a good gelatinization of the starch. Then, the beakers were removed from the bath to lower the temperature (in the laboratory environment) of the gruels to 60 °C and pre-incubated in the water bath for 20 min to integrate this temperature into the core of the product. After this time, 2.5 mL of extract or 2 g of amylase flour was introduced and incubated for 5 min. The reaction was finally stopped by passing the beakers through the boiling water bath for 10 min and the consistency of the gruels was estimated by reading their flow rate (in mm.30 $s^{-1}$) using a Bostwick consistometer at 45 °C ± 0.5 according to the method described by Bookwalter *et al.* (1968). The following Figure 1 represents the gruel cooking process used to determine the optimal germination time for each source of amylase and its best incorporation form.

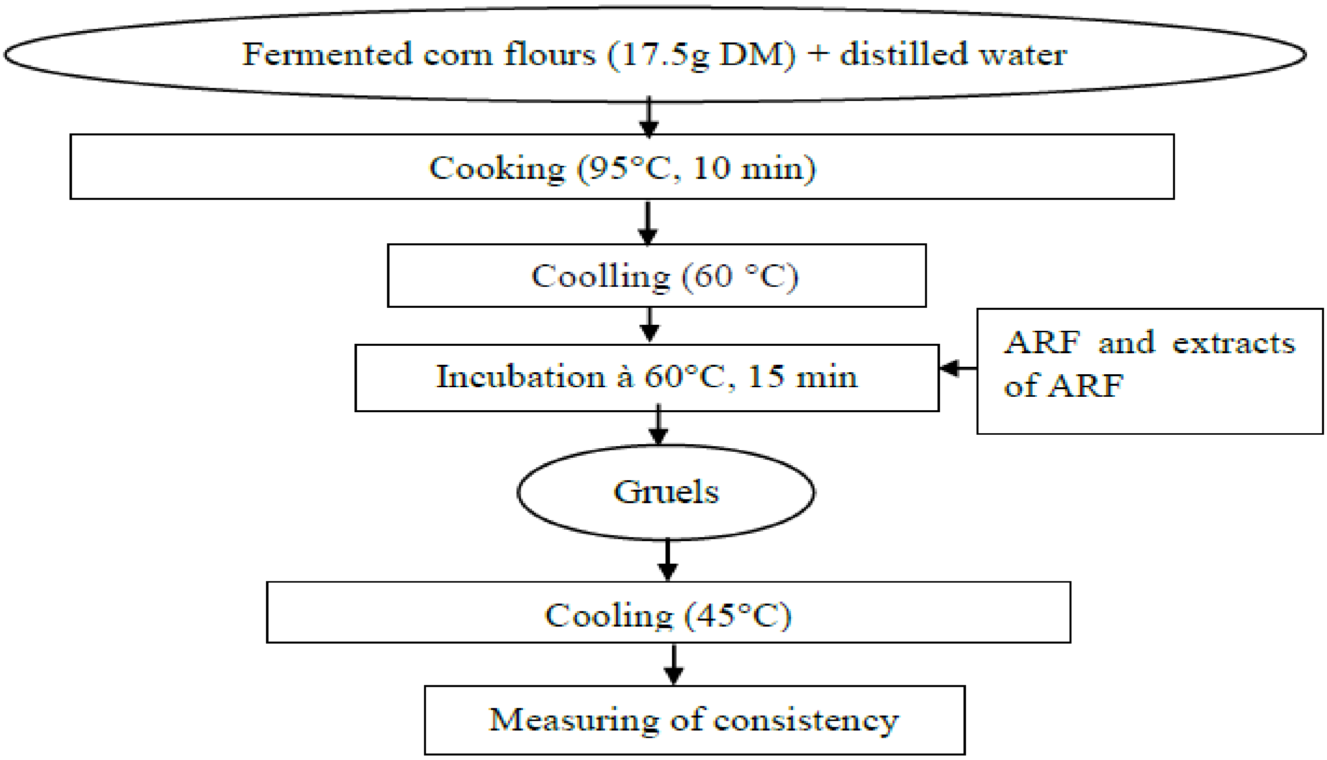


**Figure 1:** Cooking protocol of gruels.

### Preparation of traditional gruels supplemented with flours and extracts of *Coca-sr* and *Nerica L.56* (120 h and 72 h of germination respectively)

The fluidification peaks corresponding to the optimal germination time obtained for each source and incorporation form were selected for the preparation of the gruels. For this purpose, the previous cooking experiment was reproduced but over a range of 3 to 30 g of dry matter (DM) for gruels without incorporated source of enzyme compared to 10 to 25 g of DM for gruels supplemented with 2 g of ARF or 2.5 mL of extract from ARF in post-cooking. The assessment of the flow velocity was carried out as seen above. Energy densities were calculated on the basis of the dry matter concentrations of gruels with flow rates between 100-160 mm.s$^{-1}$ using ATWATER coefficients (Merril and Watt, 1955).

### Statistical analyses

The results of the analyses carried out were expressed as averages plus or minus deviations. The means were analysed by the ANOVA test at the 5 % probability threshold and the Tukey test was used to compare the means using Minitab version 17.0 software. The graphs were drawn using Excel 2013 software.

## RESULTS AND DISCUSSION

### Physical and chemical characterization of fermented maize flour

### Chemical characterization

Table 1 shows the approximate chemical composition and the content of different ions in fermented maize flour. It can be seen from this Table that the average water content is 8.00 %. This value is significantly similar to that obtained by Eke-Ejiofor (2015), on casava, potato and yam starches. However, it is significantly lower than the values (7.07-10.75 %) obtained by Diallo *et al.* (2015), on several formulations based on voandzou and wheat flour. This difference can be explained by the time and temperature of drying. This value is also lower than the 14 % humidity recommended by Ndangui (2015), which is the water threshold value that flours should contain to avoid rapid microbial spoilage and allow long-term storage in tropical areas. The ash content indicates the high extraction rate and purity index of the flour. This content is also related to the mineralization of the grind grains. Its value is 3.00 % and it is lower than the value (6.01 %) obtained by Diallo *et al.* (2015), on voandzou flour. This would be due to the nature of the flour because voandzou is a legume and maize a cereal. Moreover, it would also be the consequence of fermentation, which would have led to a reduction in the mineral component of the grains and consequently of the ashes (Tatsadjeu *et al.,* 2004; Ndangui, 2015). In addition, this element also gives us information on the whiteness index of a flour because the lower the ash content of a flour, the whiter it is. The lipid content has also been evaluated. It appears that it is 8.83 % and it is lower than that obtained by Ndagire *et al.* (2015), which was 10.4 % on bean-based flours. This would be explained by the nature of flour because legumes are richer in protein and fat than cereals. In addition, it could also be due to soaking because, as Inyang and Zakari (2008), demonstrated, during soaking, there is a reduction in lipid content due to the increased activity of lipolytic enzymes, which hydrolyzed the fats into fatty acid and glycerol. This value is significantly similar to the recommended value (8 %) for infant meal (FAO/WHO, 2006). The protein content is 12.00 % and is similar to that obtained by Khader and Maheswari (2015), on wheat flour. This protein intake is below the standard (15 %) recommended by FAO/WHO (2006), which is necessary to cover the daily intakes of children from the 6th to the 24th month age group. These analyses revealed a dietary fibre value equal to 3.26 % showing that this fermented white maize flour (*16625/SR/Cam* variety) would be sufficiently digestible as weaning flour. It is similar to the value obtained by Souza *et al.* (2018), on apple bagasse flour custard. The assessment of the carbohydrate content shows that it is 72.91 % and is therefore the most representative nutrient in this flour. That value is similar to one reported by Khader and Maheswari (2015), on Ragi flour. The evaluation of the energy content gives 419.11 Kcal and it is lower than that obtained by Tambo (2017), on unfermented maize flour. This would be due to the loss of some nutrients in the soaking water during the process of fermentation.

**Table 1:** Approximate chemical composition of fermented white maize flour (*16625/Sr/Cam* variety).

| **Composition** | |
|---|---|
| **Moisture (%)** | 8.00±1.41 |
| **Ash (% of DM)** | 3.00±0.00 |
| **Lipids (% of DM)** | 8.83±0.04 |
| **Proteins (% of DM)** | 12.00±1.41 |
| **Fibers (% of DM)** | 3.26±0.20 |
| **Carbohyatesdr (% of DM)** | 72.91±0.75 |
| **Bulk density (Kcal 100 $g^{-1}$ of DM)** | 419.11±1.52 |

Table 2 shows the approximate mineral composition of that fermented flour. Having informations on the content of different mineral elements in a food is very important in that it is use in the fight against hidden hunger, which has significantly increased for decades. It can therefore be seen from this Table that phosphorus which is an element present in biological cells plays a role in protein synthesis and cell growth, it is the most representative mineral of this flour (1465 mg.100 g-1 of DM). Its content is higher than that obtained by Villela *et al.* (2013), on corn and wheat flour. This difference can be explained by the climatic conditions of the place of cultivation, the variety, the cultivation practices and the treatment applied to the samples. Indeed, during soaking, there would have been activation of the phytases present in the corn seeds, which would have hydrolyzed the phytates and released the phosphorus. Potassium plays a very important role in enzymatic reactions as a cofactor, in the transmission of nerve impulses and in the prevention of cardiovascular diseases (Ene-Obong *et al.,* 2016). It is the second most representative mineral in this flour (102.00 mg.100 $g^{-1}$ of DM). Its content is lower than that of Hager *et al.* (2012), on maize flour (148.7 mg.100 $g^{-1}$). This would result in use by microorganisms for their enzymatic machinery during soaking. There is also a good proportion of calcium in this food (80.00 mg.100 $g^{-1}$ of DM). Calcium contributes about 2 % to an individual's body weight and is very important in the mineralization and hardness of bones and teeth. The value obtained in this study is much higher than that obtained by Pineli *et al.* (2015), on maize flour (34.00 mg.100 $g^{-1}$ of DM) and wheat flour (18.00 mg.100 $g^{-1}$ of DM). This difference would be explained by the climatic condition of the place of cultivation, the variety of the plant, the cultivation practices and the treatment applied (soaking-fermentation). During soaking, the phosphate groups carrying $Ca^{2+}$ molecules on their surfaces were hydrolyzed, which resulted in the release of calcium ions, thereby resulting in an increase in the flour. Another element that has also been evaluated is magnesium, it is involved as a cofactor in thousands of enzymatic reactions in the body. The value obtained in this study is similar to that obtained by Fasolin *et al.* (2007), on banana flour. Sodium and iron concentration have also been assessed and it appears that they are the least representatives in this flour. Iron is one of the most important minerals in human nutrition and it helps in the prevention of anaemia. The content of this element (3.00 mg.100 g-1 of DM) in the flour studied is lower than the daily demand recommended by the USDA (2002), which is between 7 and 27 mg. Sodium is mainly involved in maintaining the body's homeostasis and the value obtained in this study is higher than that of Udey *et al.* (2018), which ranged betweem 2.36-3.40 mg on sorghum flour. This difference could be explained by the soaking time of our sample because, as the same author demonstrated, the mineral content decreases with the soaking and germination time.

**Table 2:** Approximate mineral composition of fermented white corn flour (*16625/Sr/Cam* variety).

| **Mineral composition** | |
|---|---|
| **Ca (mg. 100 g$^{-1}$of DM)** | 80.00±2.83 |
| **Mg (mg. 100 g$^{-1}$ of DM)** | 31.00±4.24 |
| **P (mg. 100 g$^{-1}$ of DM)** | 1465.00±0.04 |
| **K (mg. 100 g$^{-1}$ of DM)** | 102.00±0.00 |
| **Na (mg. 100 g$^{-1}$ of DM)** | 5.00±1.41 |
| **Fe (mg. 100 g$^{-1}$ of DM)** | 3.00±1.41 |

## Physical properties

The physical properties as mass density and titratable acidity were evaluated and the results are presented in Table 3 below. It shows that the mass density is 0.70 g.mL-1 and is higher than that of Klang (2015), on millets, sorghum and maize flours. This is explained by particle size and nutrient composition, particularly proteins, as there is a significant positive correlation between these two entities (Adebowale *et al.,* 2008; Tambo, 2017). However, this mass density is similar to that obtained by Diallo *et al.* (2015), on wheat flour. It should be noted that low mass densities (less than 0.5 g.mL$^{-1}$) are recommended for the preparation of weaning gruels. The evaluation of the titratable acidity gives us a value of 13.00 mL eq of NaOH.100 g$^{-1}$ of DM. The titratable acidity value of fermented maize flour is well above the range (2.26-5.40 mL eq of DM NaOH.100 g$^{-1}$) obtained by Tambo (2017), on roasted casava and unfermented maize flour. This difference would result from the process of fermentation resulting in the release of free acids into the product leading to an increase in acidity. Also, this acidity would depend on the chemical composition of the flour, the variability of the commodity and the pH of the soil in which the corn is grown.

**Table 3:** Physical properties of fermented white maize flour (variety 16625/Sr/Cam).

| **Composition** | |
|---|---|
| **Mass density (g.ml$^{-1}$)** | 0.70±0.04 |
| **Titrable acidity (ml eq NaOH per 100 g$^{-1}$ of DM)** | 13.00±1.00 |

## Determination from the flours and their raw extracts of germinating time of corn (*Coca-sr*) and paddy rice (*Nerica L.56*) seeds that have offered the best fluidification

Figure 2 shows the fluidification kinetics of fermented maize gruel with flours and crude extracts of *Nerica L.56* rice and germinated *Cocoa-sr* maize over a period of 0 to 240 hours. It can be seen from this Figure that flow rates increase with germination time and the form of incorporation. This would probably be due to the depolymerization of the starch contained in fermented maize flour by the amylases synthesized during germination. Their action releases molecules with low molecular weight (glucose, maltose, dextrins) with low absorption and swelling capacity (Elenga *et al.,* 2012). Kanensi *et al.* (2013), also demonstrated that the amylase activity of several cereals increased with germination and soaking time. For *Coca-sr* maize ARF and raw extract, it was observed that the peak fluidification time or germination time at which the best consistency reduction was obtained was 120-168 h and 120 h respectively. Beyond these times, we notice a drop in this activity, which would come from the inhibition of the activity of amylases contained in these seeds. In addition, Nadeem *et al.* (2017), have shown that after a certain soaking and germinating time, there was a decrease in amylase activity in germinating corn seeds. Moreover, it appears from this Figure that the crude extract has a better fluidifying power than flour. This result is explained by the fact that flour has a certain starch content in addition to amylases, which could interfere with amylases for the fixation and use of water molecules, resulting in less fluidification with germinated flour. For germinated paddy rice, optimal fluidification (153 mm.30 $s^{-1}$) was observed after 72 h of germination with germinated flour and 168 h with crude extract. Like germinated corn, there is a decrease in amylase activity beyond these peaks. Thus, for an optimal use of these sources of amylases in these different forms in order to fluidify the infant gruels, they should be produced respecting the germinating timeobtained. It also appears that *Coca-sr* malt extract at 120 hours of germination would be more effective than *Nerica L.56*, whose 72-hour ARF form would be more valuable for obtaining the best results in depolymerization of starch in this unfermented corn gruel.

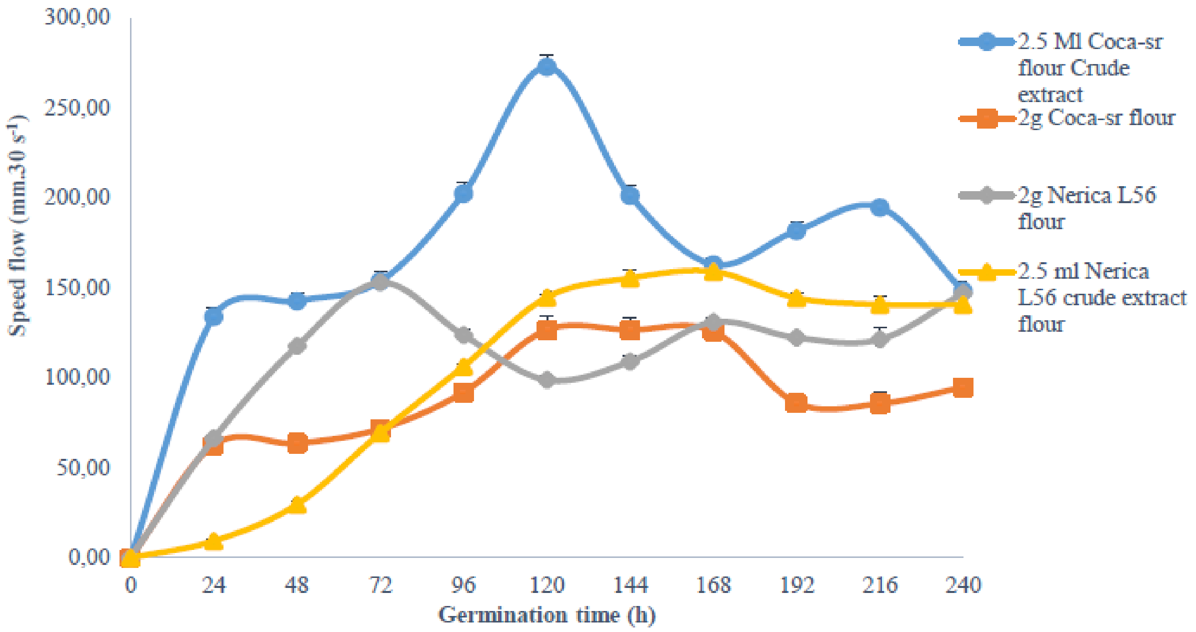


**Figure 2:** Effect of germinating time and form of incorporation on the fluidizing activity of *Nerica L.56* and *Coca-sr* germinated flours

### Evolution of the consistency of the traditional gruel of fermented maize (*16625/Sr/ Cam*) as a function of the dry matter concentration

It can be seen that in the absence of amylase sources, the prepared gruels that can be accepted by the weaning age child are very low concentrations of dry matter (less than 10 %). Thus, for these dry matter values, the flow velocity of the spray liquid increases to a value greater than 400 mm.30 $s^{-1}$. The resulting gruels are liquidify but have a low energy density (less than 30 Kcal.100 $mL^{-1}$). This fluidity of the gruels would be due to the fact that during cooking, the quantity of flour and starch did not completely fix the water molecules. This would also be attributed to the low ratio of starch-water. When the dry matter concentration is increased above 10 %, the initial fluid gruels become heavy or very thick (0 mm.30 $s^{-1}$) (Trêche *et al.,* 1992; 1993). This increase in the consistency of the gruels is attributed to the hydrating power of the starch molecule during cooking (Zannou-Tchoko *et al.,* 2011). Although having higher energy densities than the previous ones (above 40 Kcal.100 $mL^{-1}$), these gruels appear indigestible for children because they do not respect the flow rate range (100-160 mm.30 $s^{-1}$) as recommended by the WHO for infants from 6 to 24 months. Also, children after consuming a very small amount have the feeling of satiety. These traditional types of gruels are therefore inadequate for children because they cannot be use to satisfy their nutritional needs.

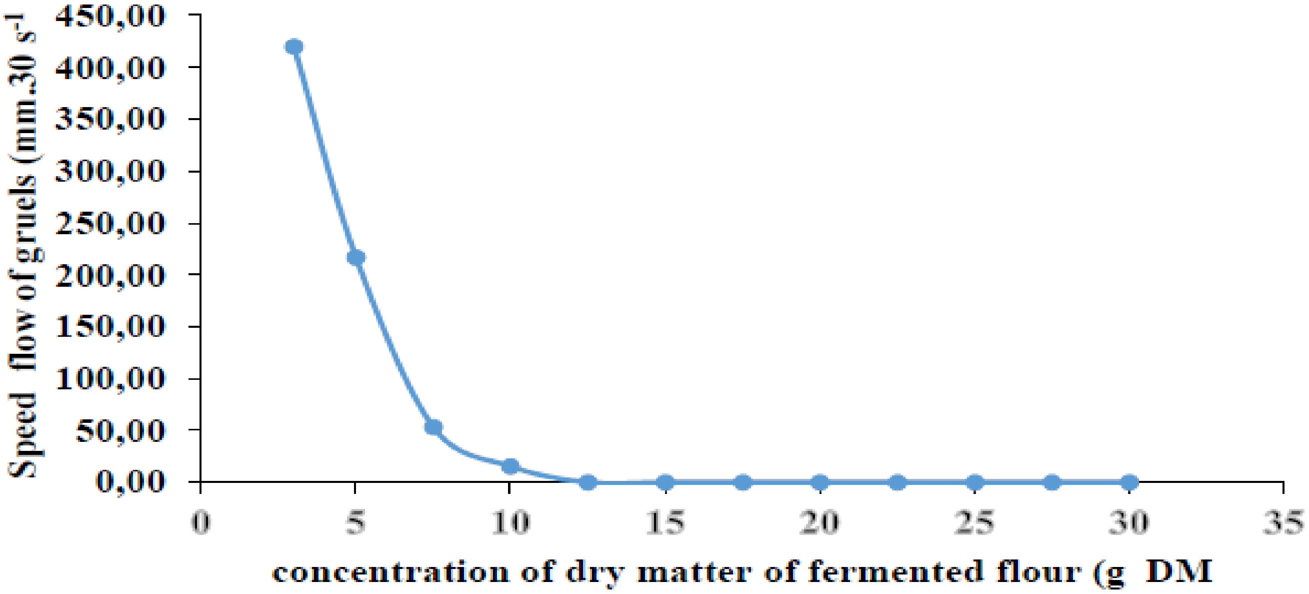
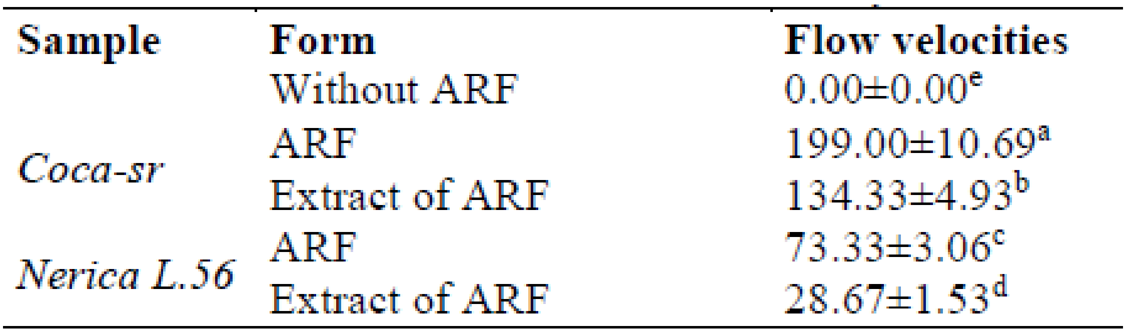


**Figure 3:** Evolution of the consistency of traditional gruel from fermented maize (*16625/SR/ Cam*) as a function of dry matter concentration

### Effect of the addition of amylase sources on the flow rates of gruel made of fermented corn at 15 % dry matter

The analysis in Table 4 shows that in the absence of amylase sources, gruel of fermented corn has no flow rate (0 mm.30 $s^{-1}$). This is explained by the fact that during cooking, the starch contained in this flour swells or gelatinizes, highlighting its -OH groups which establishes bonds with the water molecules, thus causing them to develop consistency. Such observations have also been noted by Zannou-tchoko *et al.* (2011), on cassava-based gruels and its derivative attieke. The disproportionate quantity in the flour-water ratio is also to be taken into consideration. However, when small amounts (2 g and 2.5 mL) of amylase sources are added, whatever their form and nature be, the flow rate of the gruels increases from 0 mm.30 $s^{-1}$ to more than 160 mm.30 $s^{-1}$. This would be due to the hydrolytic action of the amylases contained in these different sources which predigested the starch into molecules of low molecular weight (dextrin, maltose, glucose...) with a low water retention capacity. In addition, a significant difference ($p<0.05$) was observed between the flow rates of the gruels in the presence of the different sources of amylases in any form with increased fluidizing capacity for germinated *Coca-sr* corn. This would be explained by the nature of the amylases present in these different sources of amylase. Indeed, Klang (2015), demonstrated that the sources of amylases rich in α-amylases were more fluidifying than those rich in β-amylases. It is also due to the specificity of substrate-enzymes. Indeed, amylose and amylopectin, molecules that make up the starch of fermented gruel maize, are more sensitive to the amylases contained in germinated maize flour than those in rice. In addition, a significant difference ($p<0.05$) was observed within each source of amylase between extracts and flours with a predominant fluidification for germinated flours. This difference could be explained by the extraction technique applied, which did not allow a good extraction of amylases. It is also believed to be due to rapid denaturation of enzymes due to exposure to heat and to a modification of the active site of amylases following their contact with free organic acids present in fermented maize flour (Tambo *et al.,* 2018). Taking into account the results obtained, we can recommend the use of flours and amylase extracts to increase the flow rate of gruel made of fermented corn.

**Table 4:** Effect of the incorporation of the sources of amylase on the flow rates of gruel made of fermented corn at a concentration of 15 % dry matter.



| Sample | Form | Flow velocities |
|---|---|---|
| | Without ARF | $0.00\pm0.00^{e}$ |
| *Coca-sr* | ARF | $199.00\pm10.69^{a}$ |
| | Extract of ARF | $134.33\pm4.93^{b}$ |
| *Nerica L.56* | ARF | $73.33\pm3.06^{c}$ |
| | Extract of ARF | $28.67\pm1.53^{d}$ |

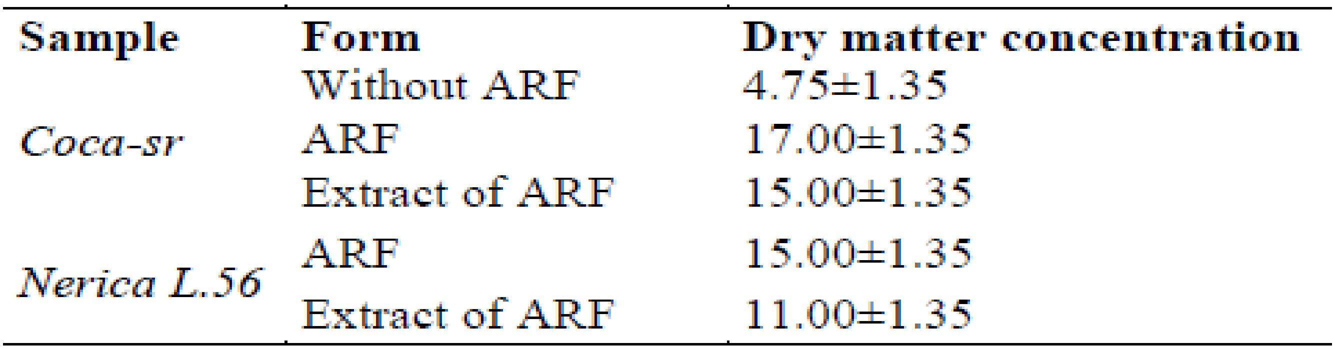
*The values carrying the different letters (a, b, c……) in the same column meaningfully differ ($p<0.05$).*

*ARF: Amylase Rich Flour.*

### Effect of the addition of the sources of amylase on the dry matter concentration of gruel from fermented maize with a flow rate between 100-160 mm.30 $s^{-1}$

Table 5 below shows the dry matter concentrations of flours to obtain flow rates between 100-160 mm.30 $s^{-1}$. It appears that in the absence of sources of amylases in both forms and nature, traditional gruel from maize has a very low dry matter concentration (4.75 g of DM) and is therefore of low nutritional value. When the different sources of amylases are incorporated, there is an increase in the concentration of dry matter. Indeed, it would take 17.00 g of DM supplemented with 2 g of germinated corn flour to obtain a flow between 100 and 160 mm.30 $s^{-1}$. This result gives us the best combination of flour and source of amylase. However, there was an increase in the dry matter concentration of the gruels when the other sources and forms of amylases were incorporated. Such observations have also been reported by Elenga *et al.* (2012), on cassava gruels supplemented with germinated maize flours. This would be due to the hydrolytic action of the amylases contained in the flours and crude extracts (source of α-amylases) which hydrolyzed the starch contained in the fermented maize flour, leading thereby to an increase in the flow rate simultanuously with the dry matter concentration (Alvina *et al.,* 1990). We can therefore recommend the use of *Coca-sr* amylase rich flour (ARF) for the preparation of gruels since it has allowed the desired flow rate to be obtained with dry matter concentrations equal to 17 %.

**Table 5:** Effect of the incorporation of the sources of amylase on the dry matter concentration of gruel made of fermented maize with a flow rate between 100-160 mm.30 s$^{-1}$.



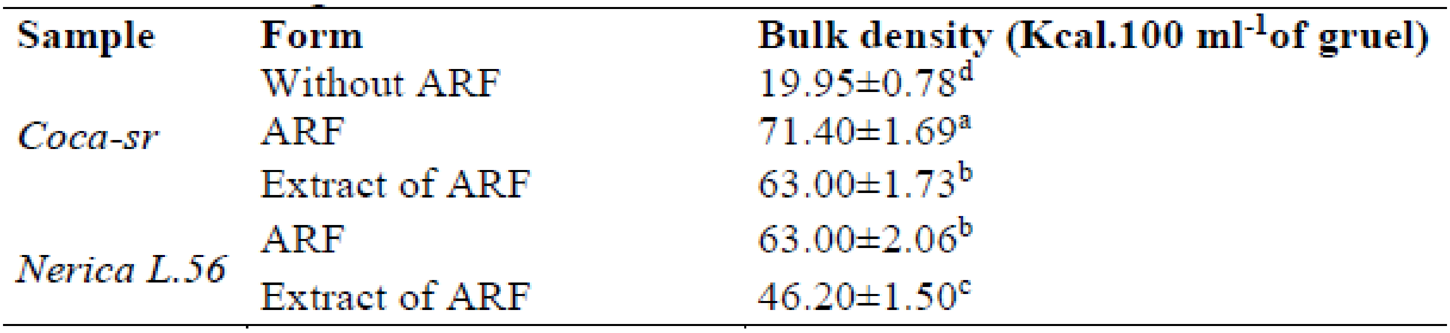
| Sample | Form | Dry matter concentration |
|---|---|---|
| *Coca-sr* | Without ARF | 4.75±1.35 |
| | ARF | 17.00±1.35 |
| | Extract of ARF | 15.00±1.35 |
| *Nerica L.56* | ARF | 15.00±1.35 |
| | Extract of ARF | 11.00±1.35 |

*ARF: Amylase Rich Flour.*

### Effect of the addition of the sources of amylase on the energy density of gruel made of fermented maize with a flow rate between 100-160 mm.30 s$^{-1}$

The analysis in Table 6 shows that in the absence of amylase sources, gruel of fermented maize is of low energy density (19.95 Kcal.100 mL$^{-1}$). The consumption of this gruel in number of daily portions (3) as recommended by the FAO/WHO report (2006), would not cover the energy needs of children (6-12 months) which is 360 Kcal of external inputs according to the same report. It is also noted that the incorporation of germinated flours and raw extracts from all the sources has improved energy density. This density falls between 46.20 and 71.40 Kcal.100 mL$^{-1}$. In addition, there was a significant difference ($p<0.05$) between the energy density of supplemented gruels and those without sources of enzyme and between the energy density of gruels supplemented with different sources and form of amylase of those incorporated. More to that, it appears that the incorporation of the sources of amylase although having improved the energy density, did not allow the preparation of a gruel with an energy value of 84 Kcal.100 g$^{-1}$ as recommended by Dewey *et al.* (2003), as the energy density covers the needs of children aged 9-11 months. It should be noted that the incorporation of the sources of protein and lipid would solve this problem. These results are lower than those obtained by Elenga *et al.* (2012), who obtained energy values ranging from 94.2-108.43 Kcal.100 mL$^{-1}$ of spray solution. This might be explain by the composition of the flours used on the one hand and the incorporation by these authors of higher levels of amylase sources on the other.

**Table 6:** Effect of the incorporation of the sources of amylase on the energy density of fermented maize gruel with a flow rate between 100-160 mm.30 s-1



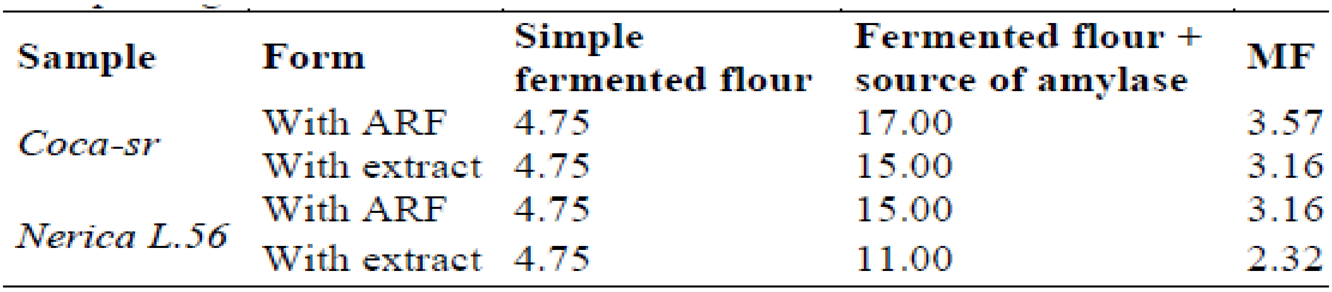
| Sample | Form | Bulk density (Kcal.100 ml$^{-1}$of gruel) |
|---|---|---|
| *Coca-sr* | Without ARF | $19.95 \pm 0.78^{d}$ |
| | ARF | $71.40 \pm 1.69^{a}$ |
| | Extract of ARF | $63.00 \pm 1.73^{b}$ |
| *Nerica L.56* | ARF | $63.00 \pm 2.06^{b}$ |
| | Extract of ARF | $46.20 \pm 1.50^{c}$ |

*ARF: Amylase Rich Flour.*

### Effect of the incorporation of sources of amylase on the multiplicating factor of the nutritional value of fermented maize porridge.

Table 7 shows that the introduction of sources of amylase in the preparation of porridges from different flours implies an increase in the dry matter concentration and the nutritional value of the porridge. As a result, the nutritional value of porridges supplemented with the sources of amylase is multiplied from 2.32 to 3.57 compared to that not supplemented, with the highest multiplicating factor (3.57) after the incorporation of *Coca-sr* ARF. These results show that the incorporation of amylase extracts and flours during the preparation of infant porridges improves their nutritional value compared to unsupplemented porridges. The multiplicating factors (MF) obtained are generally lower than those of Tambo (2017), which demonstrated that the introduction of 1 % of germinated maize flour into gruels from rotten cassava flour resulted in a flow rate between 100-160 mm.30 s-1 with a dry matter concentration of 23 % and a MF of 5.20 compared to the dry matter concentration of the traditional porridge. This difference can be explained by the nutritional composition of the flours and the treatments applied to them (fermentation, roasting, etc.). Ditto, by the difference in the rates of incorporation of amylase flours and also the substrate-enzyme specificity ratios (amylases-type of starch) involving the nature of the amylases encountered in the sources of enzyme (*Atp or* yellow maize and *Coca-sr* or white maize) as well as the differences in size and shape of the starch granules present in the Casava and maize comodities.

**Table 7**: Effect of the incorporation of amylase sources on the nutritional value of fermented corn porridge.



| Sample | Form | Simple fermented flour | Fermented flour + source of amylase | MF |
|---|---|---|---|---|
| *Coca-sr* | With ARF | 4.75 | 17.00 | 3.57 |
| | With extract | 4.75 | 15.00 | 3.16 |
| *Nerica L.56* | With ARF | 4.75 | 15.00 | 3.16 |
| | With extract | 4.75 | 11.00 | 2.32 |

*MF: Multiplicating factor ; ARF: Amylase Rich Flour.*

### Conclusion

The aim of this study was to determine the germinating time and the form of use of *coca-sr* maize and *Nerica L.56* paddy rice with the highest fluidifying power on fermented maize porridge. It appears that the germinated corn *Coca-sr* variety in the form of flour and extract presented its optimum time of fluidification after 120 hours of germination. On the other hand, an optimum time of germination was observed at 168 hours for the extract from ARF of *Nerica L.56* and 72 hours for its ARF. The composition of fermented corn flour shows that it is a good source of protein, carbohydrate and phosphorus. The use of amylase rich flours and their raw extracts from corn *(Coca-sr)* and rice *(Nerica L56)* at 2 % and 2.5 mL resulted in a reduction in the consistency of this porridge. The incorporation of germinated flour from *Coca-sr* at a rate of 2 % lead to the increasing in the fluidity of that gruel, also it energy density and nutritional value (3.57) more than with its incorporated extract and that of the different forms of incorporation of *Nerica L56* paddy rice. The 2 % use of germinated corn flour also increased the dry matter concentration of porridges without sources of amylase from 4.75 % to 17 %. Thus, it can be concluded that incorporating sources of amylase in the form of flour into traditional fermented maize porridge offers a better flow rates, better dry matter concentrations and a better energy densities. Complemented simply with a low exogenous source of proteins and lipids, it would make it an effective porridge for the fight against protein-energy malnutrition.

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