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Research Article

Improvement by a Factorial Design 2^n of the Nutritional Quality of the Gruels of Yams Intended for Child and Young Children Congoles

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Abstract: This study aims at proposing the improvement of nutritional quality and the energy density of the gruels of the flours of yam and marrow thanks to the factorial design. The production of the flour and the formulation of the flour of yam by marrows for the production of the gruels having the recommended nutritional characteristics were optimized by has factorial design. 16 experiments each one, carried out after has judicious choice of 4 variables led to has mathematical model in the form of has polygon of first degree. After analysis of the effects one the production of the flour of yam, the result shows that the factors cuts has weak effect one the answer (the content of matter dries), generally butt 0.004 to 0.5. The average of the content of dry matter is slightly closed to the dry matter of the fresh yams (38.83±0.71). The effects between the factors are also negligible. Being the formulation, the result shows that the primary product has effect one the content of proteins of the gruels. The other factors are negligible one the answer likes to their interactions. The factors and to their interactions cuts year effect slightly negligible one the dry matter of the gruels and the content total of ashes. The temperature of cooking has significant effect one the consistency (mm/30 s) of gruels whereas the other factors and all the interactions cuts has negligible effect one the answer. The formulation of the gruels containing flour of yam and marrow involves year increase in nutritional quality in particular out of proteins with 13.71 g/100 g of gruels. These results appear adapted within the framework of the fight against infantile malnutrition in the context of the local resources available.

Keywords: Children, complemented food, energy density, nutritional need, optimization

INTRODUCTION

The malnutrition remains a major problem of public health in the developing countries. The children are touched by malnutrition.

In Republic of Congo, nearly 4470 children are malnutris with 26% suffering of chronic malnutrition; 6.6% émaciés children and 14.5% having an insufficiency ponderal (EDS-Congo, 2006). The food practices are generally referred by a series of behaviors which the mother develops in particular the mode and the duration of breast feeding, the choice of the various types of complemented foods, the age of introduction and stop of breast feeding or complemented food, quantities been used for the young children. One of the relevant means to correct the nutritional status of children and the young children consists in improving the nutritional value of the local food products used in the infantile food. This improvement of the nutritional value of complemented food, depend of their composition in nutriments and their energy density. The maize, in fermented form, represents food most largely used in the preparation of food complemented which besides has a low nutritional quality owing to the fact that it represents the only basic ingredient and a low energy density because to the fact that the starch does not have sudden a preliminary technological treatment (Elenga *et al*., 2009). In addition, this fermented dough is characterized by a water content of approximately 50% thus limiting the possibilities of their conservation to long duration (FAO, 1992). Work of Trèche and Massamba (1991) showed a basic food diversity in the preparation of the gruels in the rural households congoles. The yams are tubers having significant nutritional potentialities (Trèche and Guion, 1979). Thus, to diversify food complemented and to valorise local food in the confection of complemented food our choice was made on the yams and the marrows which we will use with the state of flour. This study aims at improving nutritional quality in particular out of proteins by the production of the flour based on yam-marrow and by the increasing energy by implementing

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the précuisson and incorporation of malt. The interest of optimization was highlighted during several work at Congo Brazzaville (Silou *et al*., 2004) on in particular the extraction of essential oils. However the environmental conditions would influence the formulation of the flour of yam by roasted marrows. Thus, to try to optimize the production of the flour (starting from the formulation of the flour of yam by marrows) and of the gruel which results from this, we undertook the modeling of this production by determining the variables among the parameters which influence the answer (content of dry matter of the yam and the gruels, rate of flow of the gruels, content of proteins and ashes). A complete factorial design enables us to model the studied process. We must answer the following question: Up to what point will the addition of marrow to the yams, associated technological treatments aiming at hydrolysis partial of the starch (gelatinization followed by the incorporation of malt) make it possible to increase the energy density and the content of macronutriments of the gruels?

MATERIALS AND METHODS

Vegetable material used: The vegetable material used was consisted seeds of marrows and yams. It was bought on the level road stations and deposits of Brazzaville.

Methods of studies of the matter dries of the yams:

Parameters of studies: The indexed parameters which influence the content of dry matter of the yam are: size of the discs: $X_{1:}$ duration of blanchiment or précuisson $X_{2:}$ the temperature of précuisson $X_{3:}$ the/ratio of the water mass - mass of the tubercules of yams $X_{4.}$ These four factors have the advantage of being controllable even on an artisanal scale of production of the gruels containing flour of yams. These samples after having undergone these operations were dried with the drying oven until constant weight.

Mathematical treatment: The content of matter dries (Y) depends on the factors X_1, X_2, X_3, X_4 what results mathematically in:

$$y = f(X_1, X_2, X_3, X_4)$$

where,

y	:	The matter dries (answer)
F	:	The function answer
X_1, X_2, X_3, X_4	:	Factors taken into account

The experimentation will thus consist in highlighting the effects of some factors on the answer. Finally of account, one must answer a double following interrogation: a factor has it a specific effect given on the answer and which relation exists there between this factor and the answer?

The factorial design on two levels as developed by Davies (1954) seems sufficiently adapted to the resolution of this type of problem and it has the advantage of calling only upon very elementary mathematical knowledge (Ortigosa, 1993).

The general formula of the (N) number of experiments for a complete factorial design is:

$N = 2^K$, with K the number of variables of the factorial design

If $K = 4$, $N = 2^K = 2^4 = 16$ experiments

To build the experiment matrix, one defines:

Reduced variables X_I such as $X_I = (X_I - X_{io}) / \Delta X$

with (X_{io}) = the basic value, value in the center of the experimental field (level 0), ΔX: the step of variation = the unit of variation of the variables and two levels of variables: the high level (+1) and the bottom grade (-1).

The field of study is thus replaced by the field (-1, +1) and the 16 experiments described by the matrix are carried out by randomization (Table 1).

For a model of the first degree with interactions, the points representative of an experimental design to 4 variables are located in a space at four dimensions (a square).

The function of corresponding answer is a polynomial of the first degree compared to each factor taken independently. It is noted:

$$Y = a_o + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_{12}x_1x_2 + a_{13}x_1x_3 + a_{14}x_1x_4 + a_{23}x_2x_3 + a_{24}x_2x_4 + a_{34}x_3x_4 + a_{123}x_1x_2x_3 + a_{124}x_1x_2x_4 + a_{134}x_1x_3x_4 + a_{234}x_2x_3x_4 + a_{1234}x_1x_2x_3x_4$$

The mathematical model associated the factorial design being established with variables centered and reduced, the coefficients of the polynomial have a very simple significance then: average: a_o, principal effects: a_i; interactions a_{ij}, a_{ijk}, a_{ijkt} (Goupy, 2001).

The estimate of the coefficients is made according to calculations and data by the matrix of the effects.

Optimization of the formulation of the flour and the yam-marrow gruel:

Choice of the parameters and the level of the variables: The indexed parameters which influence the content of proteins, the rate of flow, the content total in mineral elements and the content of dry matter of the gruels are: the matter dries of starting (X_1), the built-in malt rate (X_2), the duration of cooking (X_3), the temperature of cooking (X_4). These four factors have the advantage of being controllable even on an artisanal scale of production of the gruels containing flours of yams and marrows.

The dry starting matter is the proportion of roasted marrow flour which it would be necessary to incorporate in the flour of yam so that one reaches the value desired in a complemented food. The experimental design associated with the experiment matrix is presented in Table 2.

Table 1: Experimental design

N° experience	Cut discs (X_1) in cm	Duration of precuisson (X_2) in mn	Temperature of precuisson (X_3) in °C	Report/ratio watter/ tubercules (X_4)
1	2	5	60	1,5
2	5	5	60	1,5
3	2	20	60	1,5
4	5	20	60	1,5
5	2	5	100	1,5
6	5	5	100	1,5
7	2	20	100	1,5
8	5	20	100	1,5
9	2	5	60	3
10	5	5	60	3
11	2	20	60	3
12	5	20	60	3
13	2	5	100	3
14	5	5	100	3
15	2	20	100	3
16	5	20	100	3

Table 2: Experimental design associated with the experience matrix

N° experience	Proportions yam-marrow (X_1)	Quantity of malt (X_2) in %	Duration of cooking (X_3) in mn	Temperature of cooking (X_4) in °C
1	90/10	1	5	60
2	70/30	1	5	60
3	90/10	8	5	60
4	70/30	8	5	60
5	90/10	1	20	60
6	70/30	1	20	60
7	90/10	8	20	60
8	70/30	8	20	60
9	90/10	1	5	100
10	70/30	1	5	100
11	90/10	8	5	100
12	70/30	8	5	100
13	90/10	1	20	100
14	70/30	1	20	100
5	90/10	8	20	100
16	70/30	8	20	100

Mathematical treatment: Each answer (Y) depends on the factors X_1, X_2, X_3, X_4; what translates mathematically by:

$$y = f(X_1, X_2, X_3, X_4)$$

where,

y : Answer concerned
F : The function answer
X_1, X_2, X_3, X_4 : Factors taken into account

The general formula of the (N) number of experiments for a complete factorial design is:
$N = 2^K$, with k the number of variables of the factorial design
If k = 4, $N = 2^K = 2^4 = 16$ experiments

RESULTS

Content of matter dries of the yam: study of the function answer: The mathematical model representing the content dry matter of the yam is as follows:

$$Y = 36{,}183+0{,}565x_1-0{,}500x_2-0{,}044x_3-0{,}044x_4-0{,}753x_1x_2-0{,}179x_1x_3+0{,}134x_1x_4+0{,}846x_2x_3-0{,}446x_2x_4+0{,}085x_3x_4+1{,}354x_1x_2x_3-0{,}499x_1x_2x_4+0{,}317x_1x_3x_4-0{,}315x_2x_3x_4+0{,}147x_1x_2x_3x_4$$

This relation shows that the average of the content of matter dries of the tubers of yams after these treatments carried out above is of 36.183 g/100 g of yams. Generally, the effect of the factors is almost negligible on the answer. The influence of the size of the pieces (a_1 = 0.565) has a positive effect on the answer. The influences of the duration of cooking (a_2 = -0.500), of temperature of cooking (a_3 = -0.044) and of the ratio water matter dries (a_4 = -0.004) are negative on the answer. The average of the dry matter is slightly close to the content as regards the fresh yams (38.83±0.714 g/100 g of yams).

Optimization of the formulation of the flour and the yam-marrow gruel:

Content of matter dries of the gruels: study of the function answer: The mathematical model representing the content of dry matter of the gruels is as follows:

$$Y = 24{,}361-0{,}079x_1+0{,}642x_2+2{,}084x_3+0{,}069x_4+0{,}613x_1x_2-0{,}294x_1x_3-0{,}061x_1x_4+0{,}305x_2x_3-0{,}125x_2x_4-0{,}154x_3x_4-0{,}397x_1x_2x_3+0{,}080x_1x_2x_4-0{,}111x_1x_3x_4+0{,}188x_2x_3x_4+0{,}400x_1x_2x_3x_4$$

This relation shows that the average of the content of matter dries of the gruels based on yams and of marrows after these treatments carried out above is 24.361 g/100 g og gruel. Generally, the effect of the factors is almost negligible on the answer.

The influence of the starting formulation (flour of yam-flour of marrow) i.e., of the matter dries of starting (a_1 = -0.079) has a negative effect on the answer. The influences of the built-in malt rate (a_2 = +0.642), of the duration of cooking (a_3 = +2.084) and of the temperature of cooking (a_4 = 0.069) are positive on the answer. The combined effect of the dry starting matter and the built-in malt rate (a_{12} = 0.613) like that of the malt rate and the duration of cooking (a_{23} = 0.305) have a beneficial effect on the answer.

On the other hand the combined effect of the dry starting matter and the duration of cooking (a_{13} = -0.294), of the starting matter and the temperature of cooking (a_{14} = -0.061), of the built-in malt rate and the temperature of cooking (a_{24} = -0.125) like that of the duration of cooking and the temperature of cooking (a_{34} = -0.154) have an effect negative on the answer.

Concerning the effects of three combined factors, one notes that the combined effect of the dry starting matter, the added malt rate and the duration of cooking (a_{123} = -0.397) and of the dry starting matter, the duration of cooking and the temperature of cooking (a_{134} = -0.111) have a negative effect on the answer. On the other hand the combined effect of the dry starting matter, the added malt rate and the temperature of cooking (a_{124} = 0.080) like that combined of the added malt rate, the duration of cooking and the temperature of cooking (a_{234} = 0.188) have a positive effect on the answer.

It is also noted that the 4 combined factors (a_{1234} = 0.400) have a positive effect on the answer.

Content total in mineral elements: The mathematical model representing the content total rock salt (ashes) of the pulps is as follows:

$$Y = 1{,}726+0{,}206x_1-0{,}053x_2-0{,}002x_3-0{,}002x_4+0{,}019x_1x_2+0{,}013x_1x_3+0{,}026x_1x_4+0{,}012x_2x_3+0{,}012x_2x_4-0{,}007x_3x_4-0{,}026x_1x_2x_3-0{,}013x_1x_2x_4-0{,}019x_1x_3x_4-0{,}021x_2x_3x_4+0{,}019x_1x_2x_3x_4$$

This relation shows that the average of total ashes of the gruels based on yams and of marrows after these treatments carried out above is of 1.726 g/100 g of dry matter. Generally, the effect of the factors is almost negligible on the answer. The influence of the formulation starting flour of yam marrow i.e., of the matter dries of starting (a_1 = 0.206) has a positive effect on the answer. The influences of the built-in malt rate (a_2 = -0.053), of the duration of cooking (a_3 = -0.002) and of the temperature of cooking (a_4 = -0.002) are slightly negative on the answer. The combined effect of the dry starting matter and the built-in malt rate (a_{12} = 0.019) like that of the malt rate and the duration of cooking (a_{23} = 0.305) have a beneficial effect on the answer. The combined effect of the dry starting matter and the built-in malt rate (a_{12} = 0.019), of the starting matter and the duration of cooking (a_{13} = 0.013), of the built-in malt rate and the duration of cooking (a_{23} = 0.012), of the starting matter and the temperature of cooking (a_{14} = 0.026), of the built-in malt rate and the temperature of cooking (a_{24} = 0.012) have an effect slightly beneficial on the answer.

On the other hand the combined effect of the duration of cooking and the temperature of cooking (a_{34} = -0.007) has an effect very slightly negative on the answer. Concerning the effects of three combined factors, one notes that the combined effect of the dry starting matter, the added malt rate and the duration of cooking (a_{123} = -0.026), of the dry starting matter, the malt rate and the temperature of cooking (a_{124} = -0.013), of the starting matter, the duration of cooking and the temperature of cooking (a_{134} = -0.019) added malt rate, duration of cooking and temperature of cooking (a_{234} = -0.021) have an effect slightly negative on the answer.

It is also noted that the 4 combined factors (a_{1234} = 0.019) have a positive effect on the answer. It is noted that the average of total rock salt is slightly higher than the ash content of a pilot gruel prepared exclusively with the yams (1.42±0.24 g/100 g of dry matter).

Content of total proteins: The mathematical model representing the content of proteins of the gruels is as follows:

$$Y = 13{,}707+3{,}712x_1-0{,}437x_2+0{,}023x_3-0{,}062x_4+0{,}016x_1x_2-0{,}164x_1x_3+0{,}063x_1x_4-0{,}126x_2x_3+0{,}242x_2x_4-0{,}266x_3x_4-0{,}046x_1x_2x_3-0{,}134x_1x_2x_4-0{,}173x_1x_3x_4+0{,}008x_2x_3x_4+0{,}118x_1x_2x_3x_4$$

This relation shows that the average of total proteins of the gruels based on yams and of marrows after these treatments carried out above is of 13.707 g/100 g of dry matter. Generally, the effect of the factors is almost negligible on the answer except the effect of the formulation which seemed to dissociate others. The influence of the formulation starting flour of yam marrow i.e., of the matter dries of starting (a_1 = 3.712), of the duration of cooking (a_3 = 0.023) has a positive effect on the answer. The influences of the built-in malt rate (a_2 = -0.437) and of the temperature of cooking (a_4 = -0.062) are negative on the answer.

The combined effect of the dry starting matter and the built-in malt rate (a_{12} = 0.019) like that of the malt rate and the duration of cooking (a_{23} = 0.305) have a beneficial effect on the answer. The combined effect of the dry starting matter and the built-in malt rate (a_{12} = 0.016), of the starting matter and the temperature of cooking (a_{14} = 0.063), of the built-in malt rate and the temperature of cooking (a_{24} = 0.242) have an effect slightly beneficial on the answer.

On the other hand the combined effect of the dry starting matter and the duration of cooking (a_{13} = 0.164), of the malt rate and the duration of cooking (a_{23} = -0.126), of the duration and the temperature of cooking (a_{34} = -0.266) have a negative effect on the answer. Concerning the effects of three combined factors, one notes that the combined effect of the dry starting matter, the added malt rate and the duration of cooking (a_{123} = -0.046), of the dry starting matter, the duration of cooking and the temperature of cooking (a_{134} = -0.173) have a negative effect on the answer. On the other hand the effect of the starting matter, the built-in malt rate and the temperature of cooking (a_{124} = +0.134), of the added malt rate, the duration of cooking and the temperature of cooking (a_{234} = +0.008) have an effect slightly positive on the answer.

It is also noted that the 4 combined factors (a_{1234} = 0.118) have a positive effect on the answer. The content of total proteins has in the gruels at base of the yams exclusively is of 6.06±0.08 g/100 g of dry Matter.

Consistency of the gruels: The mathematical model representing the fluidity of the pulps is as follows:

$$Y = 84{,}75+3{,}125x_1+43{,}875x_2-3{,}125x_3-62{,}25x_4-0{,}5x_1x_2+1{,}000x_1x_3-0{,}625x_1x_4+0{,}75x_2x_3-$$

$43,875x_2x_4+2,562x_3x_4-0,625x_1x_2x_3+0,25x_1x_2x_4$
$+0,5x_1x_3x_4-0,5x_2x_3x_4-0375x_1x_2x_3x_4$

This relation shows that the average of the matter dries of the gruels based on yams and of marrows after these treatments carried out above is of 84.75 mm/30 s.

The influence of the formulation starting flour of yam marrow i.e., of the matter dries of starting (a_1 = 3.125) has an effect slightly positive on the answer.

The influence of the built-in malt rate (a_2 = +43.875) has a strongly positive effect on the answer. The influence of the duration of cooking (a_3 = - 3.125) has an effect slightly negative on the answer whereas the temperature of cooking (a_4 = -62.25) has a strongly negative effect on the answer. The combined effect of the dry starting matter and the built-in malt rate (a_{12} = -0.5), of the starting matter and the temperature of cooking (a_{14} = -0.625) have an effect very slightly negative on the answer.

The combined effect of the built-in malt rate and the temperature of cooking (a_{24} = -43.875) has a strongly negative effect on the answer. The combined effect of the starting matter and the duration of cooking (a_{13} = 1.000), of the built-in malt rate and the duration of cooking (a_{23} = 0.75) as well as duration of cooking and temperature of cooking (a_{34} = +2.562) slightly have an effect positive on the answer.

Concerning the effects of three combined factors, one notes that the combined effect of the dry starting matter, the added malt rate and the duration of cooking (a_{123} = -0.625), of the added malt rate, the duration of cooking and the temperature of cooking (a_{234} = -0.500) have an effect slightly negative on the answer. On the other hand the combined effect of the dry starting matter, the malt rate and the temperature of cooking (a_{124} = +0.25), of the starting matter, the duration of cooking and the temperature of cooking (a_{134} = +0.500) have an effect slightly positive on the answer.

It is also noted that the 4 combined factors (a_{1234} = -0.375) have an effect slightly negative on the answer.

DISCUSSION

The content of dry matter of the pulps containing flour yam-marrow is 24.361 g/100 g of gruel. These values are largely higher than the maize gruels prepared according to a traditional diagram which present a content of matter dries lower than 15 g/100 g od gruel (Trèche, 1999; Elenga *et al*., 2009). This difference could be explained by the fact why the gruels of flours of yam and marrow underwent a precuisson followed by an incorporation of malt. What will allow the enzymes contained in malt to hydrolize the starch and to reduce the viscosity of the gruels. What explains increases the content of dry matter of the gruels.

The values of matter dries are close to those obtained by Michel *et al*. (2012) on the gruels containing maize-groundnut whose contents of matter dries is of 20 g/100 g of gruel. These values are higher than those of Zannou-Tchoko *et al*. (2011) for which the contents of matter dries is of 20.30±0.42 g/100 g of gruel containing cassava for a rate of incorporation of germinated maize with 5%. These values are however lower than those of Trèche (1999) having prepared gruels of energy high density with a content of dry matter of 30 g/100 g of gruel.

The content of proteins of the gruels containing flour of yam and marrow is of 13.70 g/100 g of gruel. These values are slightly lower than those obtained by Zannou-Tchoko *et al*. (2011) having mixed the cassava with the soya and, attieké with soya giving respectively 14.50 g/100 g of dry matter and 13.00 g/100 g of dry matter. They are on the other hand approximatively higher than those obtained by Elenga *et al*. (2009) and (2012) having mixed fermented corn and groundnut seeds for the which results gave contents of proteins of 12.44 g/100 g dry matter and having caused a profit of weight in the rats of 2.12±0.22 g/j against -0.25±0.14 g/j for the maize gruels prepared according to the traditional diagram.

This value is the double of the content of a protéines total in the gruel of yams exclusively (6.06±0.08 g/100 g of dry matter). This content is higher than that recommended in complemented food (Dewey and Brown, 2003; Trèche, 1999).

The gruels containing flour of yams and marrow have rates of flow of 84.75 mm/30 s for a matter rate dries of 24.36 g/100. These results are largely higher than those obtained by Elenga *et al*. (2009), on the fermented maize gruels not having undergone neither precuisson, neither incorporation of malt for the which rates of flow are null for a content of dry matter of 20 g/100 g of gruel. These results show that more the temperature increases more fluidity of the gruel decreases because the enzyme responsible for the rupture of the osidic connections linking the residues of glucose in the starch molecule is denatured. This could represents the degradation of the enzymes under the heating effect. Thus, when one considers the 8 experiments carried out at the temperature of 60°C, one notes that the flow is on average of 147 mm/30s slightly higher than the desired value (120 mm/30s). These results could contribute to the improvement of the nutritional status being able to have an impact on Immune Response of Children on like those obtained by Sari *et al*. (2014).

CONCLUSION

The formulation of glucidic food is one of the ways of the improvement of the complemented food. The environmental conditions influence much the samples of work. Thus, we could carry out a factorial design of the first degree in order to find mathematical models for the formulation of food additional

The model shows that the primary product has effect on the content of proteins of the gruels. The other factors are negligible on the answer like their interactions.

The factors and their interactions have an effect slightly negligible on the dry matter of the gruels and the content total in mineral elements.

The temperature of cooking has a significant effect on the rate of flow of the pulps whereas the other factors and all the interactions have a negligible effect on the answer.

The formulation of the gruels containing flour of yam and marrow involves year increase in nutritional quality in particular out of proteins with 13.71 g/100 g of gruels. These results appear adapted within the framework of the fight against infantile malnutrition in the context of the local resources available.

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