Solid state fermentation of the fruit meal from the breadtree (*Artocarpus altilis*) in diets for pre-fattening pigs

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The solid state fermentation of the fruit meal from the breadtree (*Artocarpus altilis*) has an adequate content of protein-energy content of Ca and P. These qualities promote their inclusion in pig diets during the pre-fattening stage, in levels from 0 and 20 % without fermentation and from 20 and 25 % in solid state fermentation for partial substitution of maize. For this study 48 weaned piglets from the Yorkshire-Landrace x Duroc hybrid with 33 d of age and an average live weight of 8.4 kg, were used in a completely randomized design with four treatments and 12 repetitions. In all treatments the maximum viability (100 %) was obtained and there were no differences for feed consumption (34.5 kg/pig). Treatments with 0, 20 and 25 % of solid state fermented fruit meal from the breadtree did not differ for final live weight (26.58, 26.39 and 25.64 kg/pig), average daily gain (429, 428 and 410 g/pig) and feed conversion (1.92, 1.93 and 2.02 kg DM.kg LW^{-1}). However, the diet including 20 % fruit meal from the breadtree reduced significantly final live weight (24.28 kg/pig) and average daily gain (377 g/pig); also it worsened feed conversion (2.18 kg DM.kg LW^{-1}). It is recommended the inclusion of 25 % solid state fermented fruit meal from the breadtree in the feeds for pre-fattening pigs as partial substitution of maize and soybean. This could allow obtaining productive results similar to those attained with conventional diets.

Key words: *breadtree fruits, solid state fermentation, pre-fattening pigs*

The constant rise in prices of grains and cereals has obliged diverse states to search for alternative feeds for animal consumption. The situation caused by the high prices of conventional feeds increases the importance of alternative feeding systems. These systems make possible that producers, especially farmers, can increase the productivity and in this way contribute to the food security and to the protection of the environment, besides increasing their income.

In view of the above mentioned reasons, in Cuba different agricultural research institutes and universities have been searching for non-traditional energy, protein and mineral sources of home production for the maximum substitution of maize and soybean with a reduction of the production cost and import dependence.

Different studies have been developed for increasing the nutritional value in feeding products. Biotransformation is one of the techniques that allow obtaining energy-protein products with different variations, where amylaceous sources have been included for improving the quality and digestibility of the product to be fermented (Elías and Lezcano 1994).

In Guantánamo province the benefits offered by the breadtree (*Artocarpus altilis*) could be exploited which is empirically used as animal feed by the farmers. However, more than 60 % of the production is lost in the fields. According to Leyva (2010), this fruit shows low crude protein content (5.8 %), but due to its soluble carbohydrate contributions could be used in solid state fermentation (SSF) processes. Also, with the addition of Vitafert a feed of great nutritive value can be obtained, according to the methodology described by Elías *et al.* (1990). The objective of this study was to evaluate the fruit meal from the breadtree (FMB) obtained through solid state fermentation, as substitute of maize in conventional diets for pre-fattening pigs.

Materials and Methods

The experiment was developed in the Pig Center "Granadillo" located in Guantánamo province, at the eastern zone of Cuba. Forty eight recently weaned animals from the Yorkshire-Landrace x Duroc hybrid of 33 d of age and an average live weight of 8.4 kg live weight were used. A completely randomized design with four treatments and 12 repetitions was applied. Each animal was considered a repetition for the variables initial live weight (LW), final LW, average dairy gain (ADG), feed conversion and consumption. The experiment lasted 42 d for this category.

Treatments consisted of the inclusion of 20 % unfermented fruit meal from the breadtree (FMB), 20 and 25 % of solid state fermented fruit meal of the breadtree (FMB-SSF) in the feed as partial substitute of maize. A control was also established. In table 1 is shown the inclusion level of each raw matter per treatment and the nutrient contribution of the formulas prepared.

For the determination of the chemical composition of the FMB-SSF, fruit were harvested in the village of Yateras, Guantánamo province. For obtaining the FMB, the procedure indicated by Leyva and Valdivié (2007) was followed.

After obtaining the FMB (39.4 %), it was mixed with

Table 1. Raw matter used per treatment and their nutrient contribution

Feeds, %	Inclusion levels of FMB, %			
	0	20 FMB	20 FMB-SSF	25 FMB-SSF
Maize meal	57.48	36.77	43.97	40.97
Soybean meal	39.49	40.20	33.00	31.00
FMB	0.00	20.00	00.00	00.00
FMB-SSF	0.00	0.00	20.00	25.00
Dicalcium phosphate	1.13	1.13	1.13	1.13
Calcium carbonate	0.50	0.50	0.50	0.50
Common salt	0.35	0.35	0.35	0.35
Choline chloride	0.10	0.10	0.10	0.10
Vitamin and mineral premix	0.45	0.45	0.45	0.45
Vegetable oil	0.50	0.50	0.50	0.50
Total, %	100.0	100.0	100.0	100.0
Calculated contribution				
CP, %	21.12	21.00	21.00	21.00
DE, MJ/kg DM	14.16	14.00	14.00	14.00
Ca, %	0.6	0.6	0.6	0.6
P, %	0.6	0.6	0.6	0.6

Diets were formulated according to the requirements of this category indicated by NRC (1998)
FMB –Fruit meal from the breadtree (unfermented)
FMB-SSF –Solid state fermentation of the fruit meal from the breadtree

water (52.8 %), urea (1.5 %), magnesium sulfate (0.2 %), mineral premix (0.5%) and calcium carbonate (0.6 %), later it was inoculated with Vitafert (5 %), according to the methodology of Elías and Herrera (2008). A plastic tank was used as fermentation chamber. Incubation was at environmental temperature for 48 h and placed in the sun for 72 h in a drying plate.

For the bromatological analysis were determined: dry matter (DM), crude protein (CP), ether extract (EE), ash, calcium (Ca) and phosphorus (P), according to the method described by AOAC (2000). Organic matter (OM) was established by the difference (100 – ashes). For determining the neutral detergent fiber (NDF) and the acid detergent fiber (ADF) the procedure of van Soest *et al.* (1991) was followed. The true protein was calculated by the difference (CP) – (NPN x 6.25). The gross energy (GE) was determined by an adiabatic calorimeter, model Parr 1281, in the Department of Zootechny of the Faculty of Veterinary Medicine, in the Federal University of Minas Gerais, Brazil.

For animal management, recommendations by López *et al.* (2008) in the Pig Rearing Manual were considered.

At the end of the experiment, viability, final LW, ADG, total live weight gain, consumption and feed conversion were evaluated. For the statistical analysis a completely randomized design was used. For assessing the results, the INFOSTAT computerized statistical package (Balzarini *et al.* 2001) was used. In the necessary cases, average values were compared through Duncan's (1955) test.

Results and Discussion

SSF has been widely used for recycling coarse materials through the application of simple technologies with which the increase of the protein levels, the improvement of the amino acid balance and the digestibility of the raw matters are attained (Durand *et al.* 1987, Elías *et al.* 1990, Mathot and Brakel 1990, Mathot *et al.* 1992, Elías and Lezcano 1994 and Pedraza *et al.* 1995). In addition of the known benefits obtained with these technologies, studies with new products for improving the efficiency of its use are still necessary.

The chemical composition of the FMB-SSF is shown in table 2. The decrease in the DM content of the product obtained (93.30 %), regarding the unfermented FMB (94.27 %), could be related to the microbial degradation processes occurring during the fermentation process and that produce volatile compounds, CO_2 and H_2O.

In the FMB-SSF there was a 12.78 percentile increase in the CP, regarding the unfermented FMB (5.2 %), where 80 % is true protein (14.43 %). This could be related to the protein synthesis produced by the microflora present in the Vitafert (a product rich in yeasts and lactic bacteria). Also it can be associated with greater ammonia retention, due to a lower pH. This brought about an increase in the CP content and allowed the development of microorganisms during the SSF. These contribute certain amount of the referred protein, besides other nutrients added to the process.

Elías *et al.* (2001) obtained similar results, on

Table 2 Chemical composition of the FMB-SSF

Nutrients	Concentration	
	FMB	FMB-SSF
Dry matter, %	94.27	93.31
CP, %	5.2	17.98
True protein, %	2.98	14.43
Ether extract, %	2.84	2.88
Ash, %	7.87	8.52
OM, %	92.13	91.48
NDF, %	11.65	13.74
ADF, %	8.05	7.67
Ca, %	0.98	3.78
P, %	0.10	0.10
Gross energy, MJ/kg DM	15.45	15.67

FMB –Fruit meal from the breadtree (unfermented)
FMB-SSF –Solid state fermentation of the fruit meal from the breadtree

fermenting mixtures of sugar cane and soybean inoculated with Vitafert, and mixtures of sugar cane, maize and soybean with Vitafert. Particularly, in the final product, high CP values (21.09 and 22.19 %) were obtained.

These results agree with Elías *et al.* (1990), Ibarra *et al.* (2002), Rodríguez-Muela *et al.* (2007) and Becerra *et al.* (2008) who reported that during SSF, the CP of the substrate is increased with the addition of non-protein nitrogen which is transformed into protein nitrogen through the fermentation process of the microorganisms present in the medium. Results from this study were superior to those of Rodríguez *et al.* (2001) who fermented a mixture of sugar cane and sweet potato (50/50) for 48 h obtaining 12 % CP.

The highest values of true protein (table 2) were found in the FMB-SSF, with 11.45 percentile increment, probably due to the bacteria and yeast development during the fermentation process (Elías and Lezcano 1994). This provoked, supposedly, the consumption of 19.08 percentiles of non-structural carbohydrates of FMB. According to Elías *et al.* (1990), the utilization efficiency of non-structural carbohydrates is of 0.61 for the protein synthesis.

As indicated by Pandey *et al.* (2001) the true protein can be an indirect way of measuring the microbial development in the SSF processes, since the microbiota established in the system transform the NPN of the urea in PN. Ramos *et al.* (2007), Rodríguez *et al.* (2007) and Rodríguez *et al.* (2010) reported similar values of true protein in fermented sugarcane and in apple products.

There was a slight increase in the content of ether extract of the FMB—SSF of 0.04 percentile units regarding the unfermented FMB. Although the lipolitic activity was not determined, it is possible that the microbial biomass established did not synthesize lipases. The increase in the NDF content of 2.09 percentiles in the FMB-SSF in solid state respecting the unfermented FMB has been also reported by Rodríguez *et al.* (2001). This increment could be related to the DM loss that would provoke effect of relative concentration from the rest of the indicators, expressed in percentile values, respecting the MS as in the case of NDF and CP.

Rodríguez (2005) has indicated that the increase in the fiber content in the SSF processes is due to a concentration of the final product, due to the use of the sugars found in the cell content by the microorganisms developed in the system.

The fact that the ADF has experienced poor or no change in its percentile relationships after SSF, could indicate that structural carbohydrates have been used in small proportions during the energetic and respiratory processes.

If taken into account that the expense in non-structural carbohydrates could be of 19.08 percentiles and that the LW increase was of 11.45 percentiles, in the fermentation process there were losses of 7.63 percentile of DM, that obviously had to increase in the rest of the non-degradable or transformed compounds by the microbiota of the system as it occurs with the minerals.

This disintegrator effect of the fiber and minerals has been demonstrated by Elías and Lezcano (1994), Rodríguez *et al.* (1998) and Elías *et al.* (2001) when they included cereal grain meals (maize), tuber roots as sweet potatoes and of oleaginous (soybean).

The ash increase obtained in the FMB-SSF in this study could be due, possibly, to the presence of the minerals that were added at the beginning of the fermentation, besides the fermentation of available sugars and starches that were used as energy source for the cell synthesis by the bacteria and yeasts developed during the process. On fermenting the sugars and starches, the ash is concentrated in the final product of the fermentation.

The unfermented FMB shows Ca concentrations (0.98 %). However, there was an increase of 2.8 percentile units in the FMB-SSF that must be related to the incorporation of the calcium carbonate (0.6 %), minerals and Vitafert (5 %). Nevertheless, the phosphorus remained in equal concentrations (0.10 %).

On the matter, Rodríguez (2005) studied different proportions of ground sugarcane stalk and yucca tuber inoculated with 10 % Vitafert in the SSF. This author found that when calcium carbonate (0, 0.3, 0.6 and 0.9 %) were added for controlling pH, the calcium level raised as the calcium carbonate was increased.

These elements, together with the high energetic contribution, situate the FMB as one of the alternative feeds to be considered for supplying animal feed security in zones where the breadtree is reproduced.

As shown in table 1, on including 20 % unfermented FMB with 20 and 25 % FMB-SSF in the diets, there was 20.71; 13.51 and 16.51 kg decrease in the amount of maize and soybean regarding the control diet. This is due to the fact that FMB-SSF and the unfermented FMB is a source of energetic compounds, owing to its richness in starch, disaccharides and monosaccharides, similar to the best cereals, roots and energetic fruits utilized for animal feeding.

The same occurred with soybean, there was a reduction (5.49 and 8.49 kg) on including 20 and 25 % FMB-SSF. This is related to the CP increment of this fermented meal when Vitafert was added as inoculum, allowing the partial substitution of maize and soybean and thus the saving of these raw matters.

The youngest animals are the ones forming the litters and dedicated to pre-fattening in the pig exploitation. Also they are the most complex from the nutritional point of view, due to their physiological immaturity and to the enzymatic changes occurring in these first life stages. The success of pig production will depend, to a large extent, from the productive management and, especially, the feeding. It is important that feeds are appetizing and balanced (Guy *et al.* 2002) for this animal category.

Table 3 shows the productive performance of the animals used in this pre-fattening stage. The indicators final LW, ADG, total live weight gain and feed conversion present significant differences between the control and 20 % unfermented. This did not occur for the rest of the treatments. This difference could be given by the presence of anti-nutritional factors in the unfermented FMB. Taking into the account the results obtained by Leyva (2010), the FMB shows 4.24 g/100 g DM and tannin and saponin concentration of 0.33 g/100 g of DM.

It is know by diverse authors (Huisman *et al.* 1990, Jansman 1993, D'Mello and Devendra 1995, Pedraza 2000, De Blas *et al.* 2003, Flores *et al.* 2005, Albert 2006 and Trompiz *et al.* 2007) that tannins and saponins present in pig and poultry diets have undesirable effects: they reduce DM digestibility, harm the intestinal mucosa, have astringent properties, bitter taste, form foams and provoke hemolysis. In addition they reduce feed consumption and, as consequence, decreases growth rate.

Regarding the control, 20 and 25 % FMB-SSF yielded the most acceptable indices in the above mentioned indicators, due to higher body weight of the animals at the end of the experiment. This indicates that the SSF had possibilities of reducing anti-nutritional substances that limited the productive performance of the animals consuming 20 % of unfermented FMB.

This decrease in conversion and the increase in ADG could be related to the presence of lactobacilli, yeasts and organic acids. This favors better absorption of nutrients from the feeds and coincide what was reported by Mulder (1996) and Anon (2000) who argued that the presence of yeasts and lactobacilli mainly, improves the productive results.

With 20 and 25 % inclusion of this alternative feed, gains of 428 and 410 g/d, respectively were attained. These values agree with the recommendations of the National Pig Group (GRUPOR 2010) in intensive rearing systems in specialized units, with the utilization of conventional feeds (concentrates). Similar results of final LW and gains reported the NRC (1998) for this pre-fattening category, although DM consumption was lower.

It is interesting to highlight that although the productive results reached with the control treatment surpassed statistically the treatment with 20 % unfermented FMB, this latter treatment showed productive indicators according to the Cuban technical instructions for this category (López *et al.* 2008).

The use of Vitafert in the FMB-SSF could have influenced on the productive results attained. González (2009) states that the utilization of Vitafert in piglets improved weight gain at weaning and decreased diarrhea incidence produced by *E. coli* and Salmonella. Also, results agree with Elías and Herrera (2008) who defined Vitafert as an activator product of fermentation that stimulates the production of organic acids, decreases pH, increases and stabilizes the protein, increases DM

Table 3. Productive indicators in the pre-fattening

Indicators	Levels of inclusion FMB, %				SE±
	0	20 FMB	20 FMB-SSF	25 FMB-SSF	
Initial live weight, kg	8.50	8.42	8.40	8.40	0.20
Final live weight, kg	26.58^{a}	24.28^{b}	26.39^{a}	25.64^{ab}	0.52*
Viability, %	100.0	100.0	100.0	100.0	-
ADG, g/d	429.0^{a}	377.0^{b}	428.0^{a}	410.0^{ab}	12.19*
Total weight gain, kg	18.06^{a}	15.87^{b}	17.98^{a}	17.25^{ab}	0.51*
Consumption, kg	34.5	34.5	34.5	34.5	-
Conversion, kg DM.kg LW^{-1}	1.92^{a}	2.18^{b}	1.93^{a}	2.02^{ab}	0.06*

[abc]Different letters indicate significant differences according to Duncan (1955)

*$P \leq 0.05$

FMB –Fruit meal from the breadtree (unfermented)

FMB-SSF –Solid state fermentation of the fruit meal from the breadtree digestibility and decreases the fractions of the cell wall of the feeding matters submitted to its action. Also, it restricts and eliminates the appearance of diarrheas in the animals.

According to Wisseman *et al.* (1989), the inclusion of acidifier probiotics in growing pig diets increases the utilization efficiency of the feeds. This statement coincides with the results obtained in which there was greater total weight in the pigs to which FMB-SSF was applied.

In other study developed by Gutiérrez *et al.* (2006) with broilers, until 42 d of age there were no significant differences with the presence of Vitafert in the concentrate or in consumption, final weight or DM conversion. Nonetheless, Vitafert produced higher DM retention, organic matter and nitrogen. In turn, there were greater weights of the Fabritius' sac and the spleen, considered as immunobiological indicators in chickens consuming concentrates with Vitafert.

Mederos *et al.* (2007) on feeding piglets from weaning to 96 d of age with high-test molasses and torula yeast (restricted diet), attained a final weight of 29.9 kg, ADG of 391 g and feed conversion of 2.48 kg feed.kg LW^{-1}. Figueroa *et al.* (1988) with the inclusion of the same feeds, fed pigs from 7 to 30 kg live weight obtaining ADG and conversion of 450 g and 3.0 kg DM.kg LW^{-1}, respectively.

González and Lara (1991) utilized Bagarip (protein-rich bagasse), a feed obtained through SSF at levels of 10 and 20 % of the pre-fattening pig diets attaining live weight gains between 333-436 g/d, as well as feed conversions between 2.59 and 3.45 kg DM.kg LW^{-1} increase. These results are similar to those obtained in this study.

The positive effects of the probiotics are not only shown at gastrointestinal tract level (GIT) but also are reflected on the productive results, as live weight gain and improvement of feed conversion (Fooks and Gibson 2002 and Coppola and Gil-Turnes 2004).

Guo *et al.* (2006) assessed *Bacillus subtilis* MA 139 cultures in pigs with improvement in feed conversion. Ayala (2005) attained results in small pig categories (piglets and growing pigs) with better physiological state, better development and better use of the feed with the utilization of a commercial probiotic.

In table 4 are set out DM conversion, digestible energy (DE) and CP. The significant difference between the control and the treatment with 20 % inclusion of the unfermented fruit is shown; not being so for the rest of the treatments. Considering the difference between the concentrate (0 %) and the different inclusion levels of SSF, 3.01, 0.81 and 0.23 MJ are required of more of energy above the control. In the case of the protein, 55, 2 and 22 g were obtained in favor, but only the negative effect produced by the addition of 20 % unfermented SSF must be considered. It is outstanding that on comparing the DM, DE and CP conversions regarding the recommendations of NRC (1998), the addition of 20 and 25 % of FMB-SSF was better.

Table 5 shows the amount of DE and CP consumed of the combination of the traditional concentrate ingredients, on taking into account the addition of 20 % FMB, 20 and 25 % of FMB-SSF, as presented in table 1.

The energy-protein consumption was lower in the studied treatments regarding the control showing significant differences ($P \leq 0.001$).

Table 6 presents the efficiency in the conversion of the conventional concentrate (control) on reducing its contribution in the treatments including 20 % unfermented FMB and 20 and 25 % FMB-SSF. This demonstrates that traditional raw matter consumption decreases as FMB is included, being higher (1.74, 1.54 and 1.51 kg) on incorporating 20 % unfermented FMB and 20 and 25 % FMB-SSF, respectively. Also, for obtaining 1 kg of ADG.kg LW^{-1}, the inclusion of non-traditional raw matter must be increased at levels of 0.44, 0.39 and 0.51 kg corresponding to its inclusion levels (20 FMB, 20 and 25 % FMB-SSF). This brings about a saving of conventional concentrate of 0.18 kg for 20 % FMB, 0.38 and 0.41 kg for 20 and 25 %, where FMB-SSF is included. The existing relationship between FMB-SSF inclusion and unfermented and the saving, demonstrate that for each unit of conventional concentrate saved, 2.44, 1.03, 1.24 times more of unfermented FMB and SSF are required.

Table 4. Conversion indicators of DM, DE and CP in pre-fattening pigs consuming FMB-SSF

Indicators	FMB, %				SE±
	0	20 FMB	20 FMB-SSF	25 FMB-SSF	
Conversion, kg DM.kg LW^{-1}	1.92^{a}	2.18^{b}	1.93^{a}	2.02^{ab}	0.06*
DE conversion, MJ.kg LW^{-1}	27.15^{a}	30.16^{b}	26.34^{a}	27.38^{a}	0.86**
Difference, MJ.kg LW^{-1}	-	3.01	0.81	0.23	-
CP conversion, g.kg LW^{-1}	404.0^{a}	459.0^{b}	406.0^{a}	42.6^{ab}	13.33**
Difference, g.kg LW^{-1}	-	55.0	2.0	22.0	-

[acb]Different letters indicate significant differences according to Duncan (1955)

*$P \leq 0.05$ **$P \leq 0.001$ ***$P \leq 0.001$

FMB –Fruit meal from the breadtree (unfermented)

FMB-SSF –Solid state fermentation of the fruit meal from the breadtree

Table 5. DM, DE and CP consumption per treatment in pre-fattening pigs fed FMB

Indicators	FMB, %, %				SE±
	0	20 FMB	20 FMB-SSF	25 FMB-SSF	
DE consumed, MJ	11.63[a]	11.30[b]	11.18[c]	11.02[d]	0.01***
CP consumed, g	173.0[a]	172.0[b]	172.0[b]	171.0[c]	0.10***

[abcd]Different letters indicate significant differences according to Duncan (1955)

***P≤ 0.001

FMB –Fruit meal from the breadtree (unfermented)

FMB-SSF –Solid state fermentation of the fruit meal from the breadtree

Table 6. Efficiency in the concentrate conversion

Indicators	FMB, %			
	0	20 FMB	20 FMB-SSF	25 FMB-SSF
Traditional raw matter consumption, kg	1.92	1.74	1.54	1.51
FMB inclusion, kg ADG.LW^{-1}	-	0.44	0.39	0.51
Concentrate saving, kg	-	0.18	0.38	0.41
Relationship between FMB inclusion and the traditional raw matter saving	-	2.44	1.03	1.24

FMB –Fruit meal from the breadtree (unfermented)

FMB-SSF –Solid state fermentation of the fruit meal from the breadtre

It was demonstrated that SSF improves the nutritive value of FMB what makes feasible the inclusion of 20-25 % FMB-SSF, as partial replacer of maize and soybean in pre-fattening pig diets, without affecting the productive performance.

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