PART OF WAGENINGEN UR

Opportunities to integrate cassava flour as partial substitute in wheat bread in Nicaragua

An evaluation of consumers, local bakeries and cassava flour processing plants

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Dedication

I dedicate this investigation to my daughter Valeria, who was born while I was here (December, 1st 2009) and to my wife for her support.

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Acronyms

CENAGRO	Nicaraguan Agricultural Census
CFP	Composite Flour Programme
CIA	Central Intelligence Agency
CIAT	International Centre for Tropical Agriculture
FAO	Food and Agriculture Organization for the United Nations
INTA	Institute of Agriculture Technology of Nicaragua
IICA	Inter American Cooperation for Agriculture
IITA	Institute of Tropical Agriculture
ITC	International Trade Centre

Abstract

This investigation evaluated the partial replacement of cassava flour (10, 15, and 20%) in wheat flour for the production of bread. The investigation involved a sensorial analysis with consumers to evaluate consumer acceptance towards wheat-cassava bread, baking trials with local bakeries to know their opinion on wheat-cassava bread characteristics at 10, 15 and 20% substitution, and an interview with processing plant managers to analyse the possibilities to process cassava flour for local bakeries.

The sensorial analysis involved a triangle and paired preference test. The triangle test was used first to identify if there was a significant sensorial difference between wheat bread and wheat cassava bread. The paired preference test was used, once a recognition level was identified to analyse if there was a significant difference in preference from consumers between wheat bread and wheat cassava bread.

At levels of 10% and 15% substitution it was found no significant difference between wheat bread and wheat-cassava bread. This means that regular consumers were not able to identify differences between wheat and wheat-cassava bread. The recognition level was found at 17% substitution.

Two paired preference test were made between wheat-cassava bread (17% and 20%) substitution and wheat bread (100%). The results showed that there is no significant difference in preference from consumers between wheat bread and wheat cassava bread up to 20% substitution. For this reason, it is concluded that there is a good level of acceptance from the consumers towards wheat-cassava bread.

Most of the characteristics of wheat-cassava bread (taste, texture, colour and aroma) were accepted by local bakeries with the exception of volume. It was found that there is a direct relation between the use of cassava flour and the volume of bread. The higher the partial substitution of cassava flour the lower the volume. According to local bakeries, the best bread making potential of cassava flour is as partial substitution of 10% in wheat flour.

The main obstacle identified for processing plants to produce cassava flour for human consumption is the lack of processing equipment and artificial driers for rainy season. Their major concern to develop a new market channel with local bakeries is the constant demand of high quality flour from local bakeries. On the other hand, it was concluded that cassava flour can be produced at least 15% cheaper than wheat flour.

If in Nicaragua, cassava flour is used as substitute of 10% in wheat bread, wheat imports could be reduced in 15% (14,844 tons) since approximately 66% (2/3) of total wheat imports is transformed into wheat flour. In terms of value this represent U$ 5,164,650 U$ that could be invested in the country and generate value to the existent cassava chain.

INTRODUCTION

1.1 Introduction

The following document is a research on the opportunities to integrate cassava flour as partial substitution in wheat flour for the production of bread. The analysis of this research is on: a) consumer acceptance towards wheat-cassava bread, b) the opinion of local bakeries on the bread making potential of cassava flour at three different levels of substitution in wheat flour (10%), (15%) and (20%), and c) the opinion from the cassava processing plant managers in the possibilities to supply local bakeries with cassava flour.

The scope of this research mainly at the market level in which is investigated the opinion of consumers and the opinion of local bakeries which in this case represent the potential industry. On the other hand, the opinion of processing plant managers contribute to the production oriented perspective analysis of the actual situation of the chain. The stakeholders analysed in this research are: the consumers, local bakeries and the processing plants.

The strategy used in this research for the collection of the primary information is a combination of an experiment and interview with local bakeries, an interview with processing plant managers, and two types of sensorial tests with consumers: a triangle and paired preference test. A desk study was carried out to find out the secondary information on the bread making potential of cassava flour, nutritional value of cassava and safety aspects, and the different uses of cassava in the world.

The experiment with local bakeries consists in the substitution of cassava flour on wheat flour in a regular formula made by a local bakery for the production of plain bread. The triangle test is used to analyse first, if there is a sensorial observable difference between wheat bread (100%) and wheat-cassava bread at the proposed levels of substitution (10, 15, and 20%). Second, a paired preference test is used to determine if there is a significant difference in preference from consumers between wheat and wheat-cassava bread.

The aim of this research is to contribute with information on the opportunities to integrate cassava flour in wheat bread production in Nicaragua.

The origin of this idea comes from the limited market alternatives from the cassava flour processing plants and cassava producers in Nicaragua. This idea is a potential solution for the cassava flour processing plants which are limited to the production of flour for animal feeds and cassava producers. The partial substitution of 10%, 15% and 20% of cassava flour in bread can generate a significant potential market demand in the domestic market. Moreover, by being a partial substitution on wheat flour, it can become a more achievable demand to meet.

The motivation of doing this research is that the results can become a starting point for the development of a new market channel for cassava producers and processing plants in Nicaragua. In addition to this, the partial substitution of cassava flour on wheat flour can reduce the Nicaraguan imports of wheat (108,299 tons in 2009) and wheat imports dependency, reduce bread costs, contribute on food security, and generate economic growth through the industrialization of cassava.

1.2 Background Information

The following information is on the world cassava production and actual situation of cassava production in Nicaragua. It is also included a small description of the wheat millers of Nicaragua and the Nicaraguan wheat imports for the further analysis of potential quantities that could be replaced with the partial substitution of cassava flour.

1.2.1 Cassava World Production

Cassava (Manhiot esculenta Crantz) is a perennial tuber grown in the tropics. It is composed of; water 62 to 65 percent, total carbohydrate 32 to 35 percent, protein 0.7 to 2.6 percent, fat 0.2 to 0.5 percent, fibre 0.8 to 1.3 percent and ash 0.3 to 1.3 percent (Kay 1987, cited by Wenham, 1995). According to FAO (2008), Cassava is the developing world's fourth most important crop after wheat, rice and maize. Moreover, it represents a staple food for nearly a billion people in 105 countries from Tropical Africa, Asia, and Latin America.

According to FAO statistics division (2010), in the year 2008, the estimated global production was 232,950,180 tons. From this quantity produced, the 51% comes from Africa, 34% from Asia and 15% from the Americas especially south America. The first five countries producers of cassava in the world are: Nigeria, Thailand, Brazil, Indonesia, and Congo Democratic Republic. (FAO, 2010).

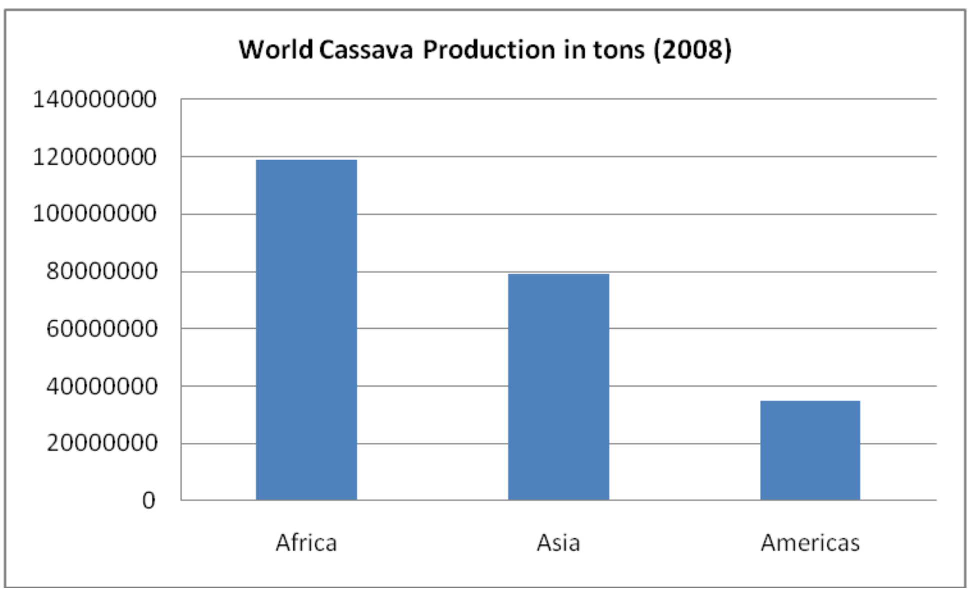

Figure 1. 1: Distribution of World Cassava Production in Tons

Source: FAO Statistics division (2010)

1.2.2 Production of Cassava in Nicaragua

In Nicaragua, 12,000 hectares of Cassava are cultivated (FAO, 2010), 0.006% of the total cultivated land (1,930,770 hectares). The total production in 2008 was 115,000 tones. From this quantity, 70% is grown in the South Atlantic Autonomous Region especially in Nueva Guinea and 30% on Masaya and Leon (IICA, 2004). The production cycle in Nicaragua begins during the winter (rainy season) from May to October and usually ends in summer during April and the beginnings of winter in May.

According to FAO statistics Division (2010), in the year 2008 the average yield was 95,883 hectograms per hectare, corresponding to 9.583 tons per hectare.

Most of the cassava produced in Nicaragua is still sold fresh in the domestic markets for human consumption. However, since the Signed of the Dominican Republic and Central America free trade Agreement (DR- CAFTA) in 2006, the exports to the United States market increased in 81% from 153 tons in 2006 to 846 in 2009 (ITC, 2010).The overall exported quantities to the main foreign markets Honduras, Salvador and the U.S has decreased in 13.4 % from 4,814 tons in 2006 to 4165 tons in 2009. Please refer to following chart to see the behaviour of exports. However, the overall exports in value increased in 40% from 602 U$ thousand in 2006 to 1,015 U$ thousand in 2009 (ITC,2010).

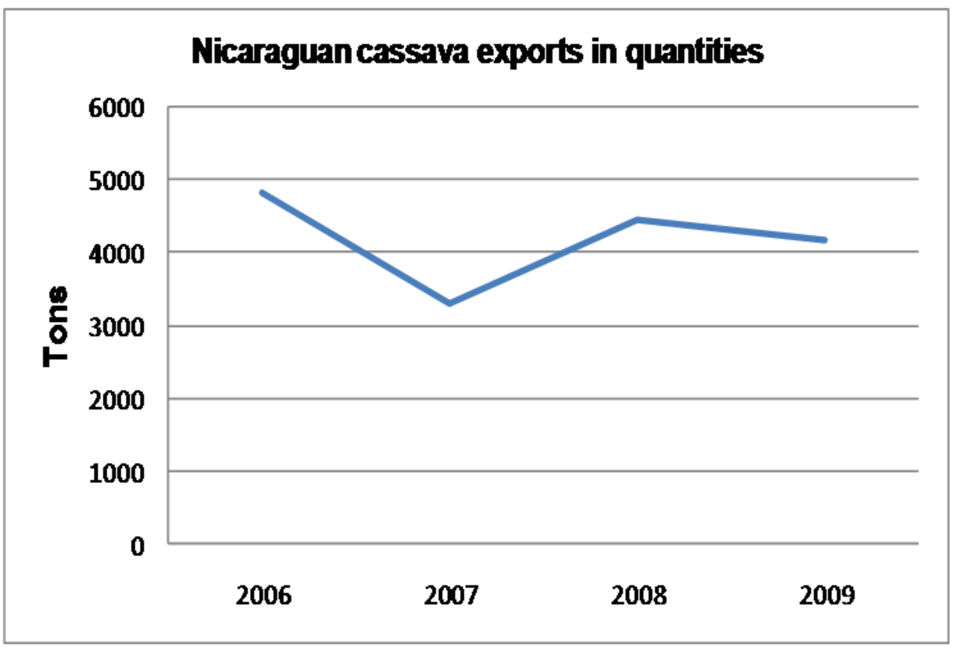

Figure 1. 2: Nicaraguan Cassava exports in quantities (2006-2009)

Source: International Trade centre (2010)

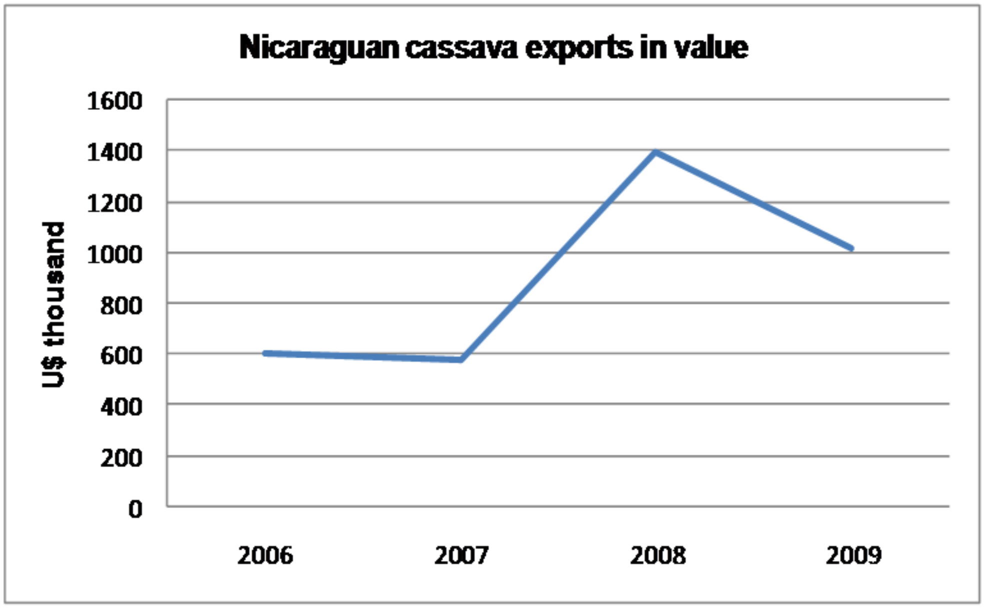

Figure 1. 3: Nicaraguan cassava exports in values (2006-2009), U$ thousand

Source: International trade centre (2010)

The increase of exports of fresh cassava roots also increases the availability of second hand quality of cassava in local markets. This is because not all the cassava harvested meets the foreign market quality requirement due to physical damage while being harvested. According to Christopher, Wheatley (1989), normally about 80% to 90% of the cassava roots are of commercially quality with little or nonphysical damage, 5-10% is commercial with little physical damage in domestic markets and 5-10% is not commercial at all. Besides this, among the foreign market requisites for fresh cassava tubers is that they should have a uniform shape and size. This increases the percentage of tubers that do not meet the foreign quality requirements. In Nicaragua it is said that approximately from 30% to 40% of the tubers harvested do not meet the export market quality requirements. This can be an opportunity for the flour and starch industries, taking in count that the quantities sent at once are high (containers of 20,000Kg).

The cassava flour processing plants are limited in the country. Most of the processing plants are into the production of cassava into flour for animal feeds. However, the prices of cassava flour for animal feeds are low between 12 to 14 U$ per 50 kg bags. Taking in count that from (3) 50 kg bags, (1) 50 kg of cassava flour is produced for animal feeds, it does not represent good prices to cassava producers. The region in Nicaragua where the industrialization of cassava is more significant is in the city of Leon and Chinandega where the Challenge Millennium Cooperation program from the United States has supported the cassava chain in promoting the associativity of producers with producers and the adding value of produce. However, most of the plants are into the processing of waxing fresh tubers for foreign markets.

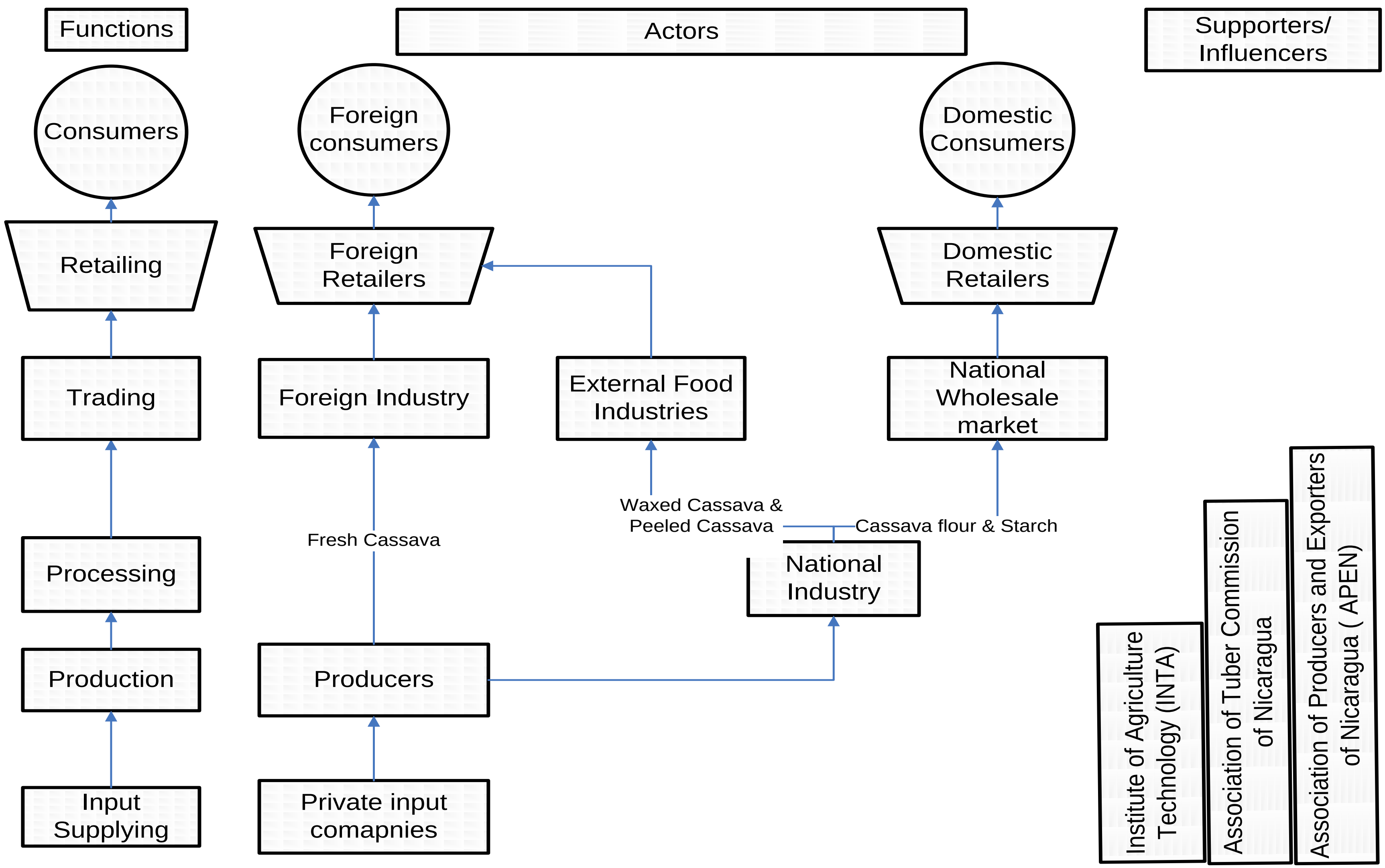

Figure 1. 4: General Cassava Chain in Nicaragua

Source: (IICA,2004)

1.2.3 Imports of Wheat Flour

In Nicaragua there are three main wheat processing plants; Harinera Agroindustrial de Nicaragua (Harinisa) in the city of Leon, Gemina in the city of Chinandega and Molinos de Nicaragua (Monisa) in the city of Granada. These are the three major importer companies of wheat and distributors of wheat flour in the country. According to a report from the Ministry of Economy of Nicaragua (2010), in the year 2004, there were 2224 local bakeries in the country, from which 90% (2003) are located over west side of the country, in the Pacific Coast and 10% (221) are located on the East side, on the Atlantic Coast. Most of the bakeries in Nicaragua are artisanal and produce low cost bread that can be affordable by the consumers.

The imports of wheat of Nicaragua come from the United States of America and Canada. Please refer to the following graphs to see imports in quantities and values.

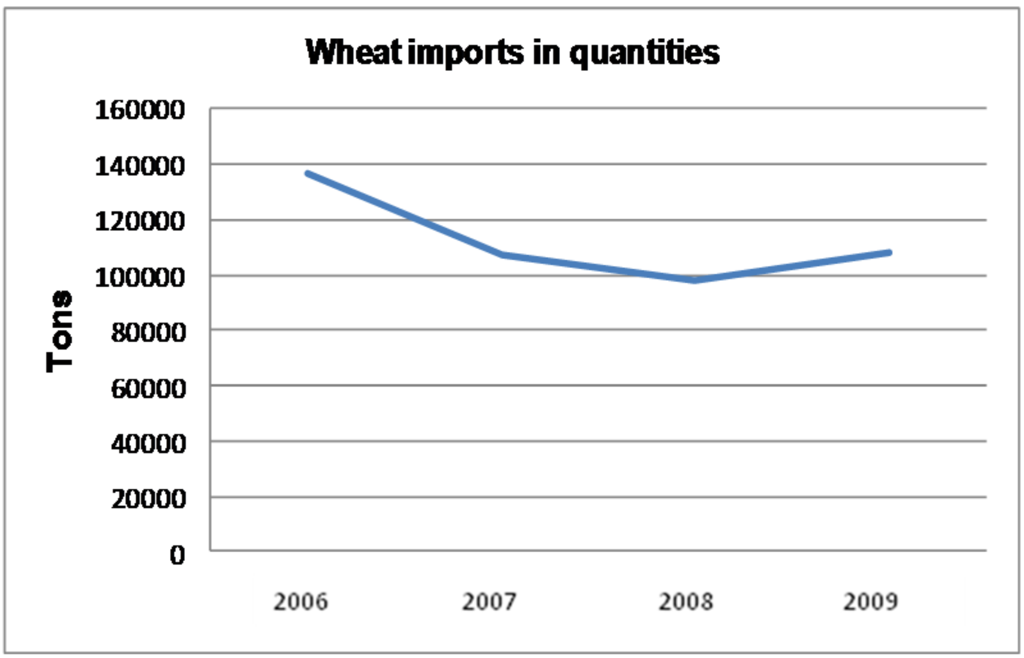

Figure 1.5: Nicaraguan Imports in quantities (2006-2009)

Source: International Trade centre (2010)

Figure 1.6: Nicaraguan Imports in Value (2006-2009)
Source: International trade centre (2010)

1.3 Problem Statement

There is a limited market demand for cassava flour for human consumption in Nicaragua. In the actuality most of the cassava flour produced is for animal feeds. However, the prices for cassava flour for animal feeds are low (12 US to 16US/50 kg bag) so the prices offered to farmers are also low (2-3 U$/50 kg bag) and therefore farmers are not interested in supplying processing plants. This affects the production capacity of processing plants and leads to less market alternatives to cassava farmers. The owners of this problem are the cassava flour processing plants.

A possible solution to increase cassava flour demand as well as price is the use of cassava flour as partial substitute of wheat flour (10%, 15%, 20%) for bread making since bread is part of Nicaraguans basic diet. However, it is unknown if wheat-cassava bread is accepted by consumers, second, what is the opinion of local bakeries on wheat-cassava bread characteristics and third, what are the possibilities for processing plants to supply local bakeries with cassava flour.

1.4 Study Objective

To identify the opportunities to integrate cassava flour as partial substitute in wheat bread in Nicaragua

1.5 Research Questions

Main Research Question: What are the opportunities to integrate Cassava flour as partial substitute in wheat bread in Nicaragua?

Research Question 1: Is wheat-cassava bread accepted by consumers?

Sub-question 1: Is there any observable sensorial difference between wheat bread and wheat-cassava bread?

Sub-question 2: Is there any significant difference in preference by consumers between wheat bread and wheat-cassava bread?

Research Question 2: What is the opinion of local bakeries on wheat-cassava bread characteristics?

Research Question 3: What is the opinion of processing plant managers in the possibilities to process cassava flour for local bakeries?

1.6 Justification

The reason to do the research on the potential use of cassava flour at the market level in the chain is because the power in the chain relies on the consumer. Therefore, it is required to know what consumers and bakers think about the composed wheat-cassava bread before developing any intervention from the production oriented perspective. The reason of doing the experiment on the partial substitution of cassava flour in wheat bread is because wheat bread is part of Nicaraguan everyday basic diet. The proposed levels of cassava flour substitutions on wheat flour (10, 15 and 20%) come from an investigation on a global market study by FAO in 2004 which says that cassava flour can be used up to 20% substitution for bread making.

Another reason of doing this investigation is that local bakeries are the most important market for flour in Nicaragua which depends 100% on wheat flour imports.

In addition to this, the existent market channel (animal feed industries) pay low prices for cassava flour (12-16 U$ per 50 kg) since maize can be imported from the United States at the same price and with a high level of protein content. For this reason it is required to do research on a different market channel which could offer high prices to farmers. Finally, the tubers commission of Nicaragua has a great interest on this research because the results can contribute for the further development of a new market channel for cassava producers and processing plants.

1.7 Research Context

The interest of tropical countries to reduce the dependency partially or fully on wheat imports through the integration of a tropical crop has always been there. In 1964, the Food and Agriculture Organization of the United Nations initiated the composite flour program (CFP) to develop bakery products from locally available raw materials, especially Cassava, Corn, and Sorghum. This program was directed to those countries which could not meet their wheat requirements. The first result of the program were that even though the bakery products were of good quality, the texture and palatability of the composite flour bakery products were different from those made from wheat flour. (Grace, 1977)

The international Institute of Tropical Agriculture (IITA) has also worked in the partial substitution of cassava flour into wheat bread production. In Nigeria, (IITA) developed a simple process for producing high quality cassava flour suitable for baking in response to the increase in prices of wheat. The flour was successfully tested in bakeries and biscuit factories. (Nangano et al.,2005). In Latin America the cassava flour also called farihna de mandioca has been used for bread making on bread called “pan de bono” originally from Colombia as well as “couac” in Brasil.

In Nicaragua, cassava does not form part of Nicaraguans basic diet. The Nicaraguans basic diet is composed of basic grains, especially, maize, beans and rice. However, cassava is regularly consumed as a source of carbohydrates and substitute of rice.

The main market channel of cassava is still the domestic market where cassava tubers are sold fresh. The Dominican Republic and Central free trade agreement which was signed with the

United States in 2006 has given new opportunities for new market to producers; however cassava is mostly sold as fresh and fresh-waxed without generating great value added to it. Even though, there are some cassava processing plants of starch, flour for animal feeds and chips, the industrialization of cassava is still limited in the country. This limits the market alternatives for cassava producers.

The Institute of Agriculture and Technology of Nicaragua has done research on seed cassava varieties and agricultural practices to increase productivity. However, little or none research has been done in the processing of cassava flour for human consumption and the use as partial substitute in bread making. Most of the Agriculture investigations are still on agricultural practices and seed varieties to increase production and productivity of basic grains to ensure food security in the country.

1.8 Definitions of Concepts

Triangle test:

A sensorial test used to determine whether a sensory difference exists between two products. (Meilgaard et al., 2007).

Paired Preference test:

A sensorial test used to determine whether the prototype is preferred over the current product. (Meilgaard et al., 2007).

Recognition threshold:

It is the level of a stimulus at which the specific stimulus can be recognized and identify. (Meilgaard et al., 2007).

Absolute threshold:

It is the lowest stimulus capable of producing a sensation. (Meilgaard et al., 2007).

Significance difference:

The amount of evidence required to accept that an event is unlikely to have arisen by chance. P< 0.005. (Meilgaard et al., 2007).

Wheat bread:

Bread made of 100% wheat flour.

Wheat-Cassava bread:

Bread made with wheat flour and wheat- cassava flour.

Actors or stakeholders: are those who are commercially involved such as (producers, traders, retailers, consumers) in the chain and also chain supporters and influencers who are also called indirect actors (bankers, credit agencies, government). (KIT,Faida, IRR, 2006).

Supply Chain: is a set of linkages between actors where there are no binding or sought-after formal or informal relations, except when the goods, services and financial agreements are actually transacted. **(**KIT,Faida, IRR, 2006).

Value Chain: is a specific type of supply chain where the actors actively seek to support each other so they can increase their efficiency and competitiveness. **(**KIT,Faida, IRR, 2006).

2. LITERATURE REVIEW

2.1 Bread making Potential of Cassava Flour

2.1.1 Cassava Flour as full substitution of wheat flour

Cassava flour by having no gluten has been of interest for many researchers for the production of non-gluten bread that can be used for Celiac disease patients. According to Lundin et al., (1993), “Celiac disease is most probably an immunological disease, precipitated in susceptible individuals by ingestion of wheat gliadin and related proteins from other cereals”. It is for this reason that celiac patients must stick to a non-gluten diet throughout their lives. Besides the use of cassava bread as an alternative solution for Celiac disease patients, the use of cassava flour has been investigated to reduce the imports of wheat in tropical countries. However, “the bread making potential of Cassava flour is limited due to the poor gas retention which affects volume of bread” (Defloor, 1995). Because of this reason, Defloor states that the surfactants and viscosity enhancers used in the preparation of non-wheat dough.

On the other hand, wheat flour is recognized to have unique bread making potential due to the gluten proteins. According to Finney and Barmore (1948) cited by Defloor (1995), “When wheat flour and water are mixed, the gluten proteins develop into visco-elastic network which imparts gas retention properties to the resulting dough”. Therefore, the gas retention properties are essential for dough leavening during fermentation and for a fine airy crumb structure after baking (Defloor, 1995).

According to Pasqualone et al., (2010), at present there are many types of non-gluten free bread however there are still problems regarding the bread making potential. Many gluten free breads which are being produced for commercial purposes are in inferior in quality compared to the gluten breads.

Pasqualone et al.,(2010), evaluated the effectiveness of the use of cassava flour in bread-making by adding only egg white and/or extra virgin olive oil without the help of any hydrocolloid or industrial improver. Moreover, a sensory acceptability with consumers was assessed. He concluded that significant improvement of the sensory characteristics of cassava bread was achieved by adding egg white and extra virgin oil to the cassava bread formulation. Moreover, the breads containing both ingredients (egg white and extra virgin olive), showed an improved loaf with a softer texture, a more regular crumb structure and reduced gumminess compared with pure cassava bread. The results of the sensorial tests showed that the breads made with egg white and extra virgin olive oil obtained the best scores from the panellists which resulted as attractive as wheat bread. Please refer to following table to see the chemical and physical characteristics of the different types of bread.

Table 2. 1: Chemical and Physical Characteristics of bread samples and results of the statistical analysis at p<0.05

	Type of Bread				
Determination	WB	CB	CBO	CBE	CBOE
Specific volume(mL/g)	4.04^{a}	2.24^{b}	2.75^{bc}	3.09^{c}	3.93^{a}
Protein content (g/100 g dry solids)	10.2^{a}	1.3^{b}	1.3^{b}	5.4^{c}	5.3^{c}
Crumb moisture (%)	31.7^{a}	53.3^{b}	52.4^{b}	37.0^{a}	35.8^{a}
Crumb firmness (N)	4.13^{a}	9.14^{b}	7.87^{c}	5.27^{d}	$4.67a^{d}$

WB=Wheat bread, CB=Cassava bread, CBO=Cassava bread with oil, CBE=Cassava bread with egg white, CBOE=Cassava bread with oil and egg white.

Source: Pasqualone et al., (2010).

Eggleston et al., (1991), stated that new and alternative nutritious bread can be produced from cassava flour fortified with 20% raw or roasted soy flour using locally available margarine with egg white, together or without Xanthan gum. He concluded that margarine with egg white, increased control loaf volumes by 29% and the addition of Xanthan increased oven rise and volumes by 35%.

He states that even though many researchers have found gluten substitutes such as :self-emulsifying glycerol monostearate (GMS), wheat/rye, pentosans, gums, among them: methyl cellulose and Xanthan, and Pregelatinized or extruded flurs and starches, very limited or non-implementation in developing countries have been made. The main reason is because the gluten substitutes are rarely available locally or the equipments to produce them is very expensive. Then if the gluten substitutes are imported the prices of bread go up. Therefore, the success of non-wheat bread is the use of locally available gluten substitutes.

According to a study on the processing of cassava by Grace (1977), the bread of non-glutenous flour was characterized of having a crumb structure of cake rather than bread. Therefore, they may not be considered acceptable by people who are accustomed to conventional bread.

2.1.2 Cassava Flour as partial substitution in Wheat flour

Due to the limited bread making potential of cassava flour as explained by Defloor, (1995) caused by the poor gas retention of non-wheat batters and the limited gluten substitutes and technologies in tropical countries, cassava flour has been more applied as partial substitution of wheat flour as well used in composed flours. The Food and Agriculture Organizations of the United Nations (FAO) started the composite flours program in the year 1964 with the main objective to develop bakery products with locally available raw materials in tropical countries especially with countries which could not meet the requirements with wheat imports. It was found that the upper limit of substitution was 10%, above that level the volume of bread declines (Grace,1977).

However, another results of the program showed that with the addition of a bread improver such as calcium stearyl lactylate or adding a higher percentage of protein and sugar, bread with an acceptable loaf was obtained up to 30% substitution. The program concluded that even though the results of the bakery products obtained from the composite flours were of good quality, similar in some of their main characteristics to wheat-flour bread, the texture and palatability of the composite- flour bakery products were different from those made from wheat flour". (Grace, 1977)

The Federal Institute of Industrial Research in Oshodi (2005), in Nigeria, concluded in an investigation that Cassava flour can be successfully mixed with wheat flour for bread at varying levels of substitution; 10-15%, being the most acceptable for bread making, while 15-20% is acceptable for confectioneries and other baked products. On the other hand, In Ghana, consumers have accepted as levels as high as 35% cassava flour content in Sweet biscuits and 60% in hard dough biscuits. Eggleston Gillian (1991), states that: "An acceptable loaf that resembles whole wheat bread can be obtained with up to 30% substitution of wheat flour with cassava flour, provided that precisely the "right amount" of water. As the level of substitution of cassava flour for wheat flour increases the water requirement also increases. In 100 grams formula at 10% of substitution of wheat flour with cassava flour, 0.25 cup of water and 1 extraspoonful is required. At 20% substitution, 0.25 cup of water and 2 extraspoonful of water are required. At 30% substitution, 0.25 cup of water and 3 extraspoonful of water are required. (Eggleston 1991).

According to Giami et al. (2004) and Akubundu (2005) cited by Eddy et al., (2007) , up to 20% substitution of wheat flour for cassava flour had no adverse sensory and organoleptic effect on bread. Bread with 10% and 20% of cassava flour were not significantly different in most sensory attributes. Bread baked with 10% and 20% cassava flour was rated higher in aroma, colour, flavor, general acceptability and preference to buy than 100% wheat flour.

Defloor et al., (1995), investigated the influence of the partial substitution (15 and 30%) of wheat starch, cassava starch and cassava flour on wheat flour for bread making. The bread made with starch had better volume and external characteristics than the bread made with cassava flour. However, the structures of bread did not show a drastic difference on the different levels of substitution with the exception of cassava flour for wheat flour in 30%. It was concluded that at the different levels of substitution the decrease of loaf volume was more remarkable than the bread properties.

An organoleptic study made by Gim, N.G and Lin, Khor (1978), on the different levels of cassava flour substitution (up to 30%) and winged bean showed that the overall score for bread wih 10% cassava flour substitution on wheat bread was higher than the control. Please refer to following table to see results.

Table 2. 2: Scores for the Organoleptic characteristics of bread with different levels of the cassava flour and winged bean flour.

Bread samples		Crust Color	Crust toughness	Crumb Color	Crumb texture	Flavour	Crust/crumb ratio	Overall Score
100% wheat flour (control)		4.25	4.08	4.18	4.27	4.18	4.18	25.14
90-10% (Wheat-Cassava)		4.43	4.14	4.71	4.86*	4.71	5.00*	28
80-20%	**"**	3.14	3.57	4.14	3.71	3.29	3.86	21.71
70-30%	**"**	4	3.57	4.14	3.71	3.57	3	21.43
60-40%	**"**	2.00 *	2.29*	2.71*	1.86*	1.86*	2.42*	13.00*
50-50%	**"**	2.14*	2.43*	2.71*	1.86*	2.43*	3	14.57*
75-20-5% Wheat-Cassava winged		4.57	3.86	4.14	4.57	3.43	5	25.57
70-21-9%	**"**	2.57*	3.13	2.86	3.57	2.86	3.29	17.71

Scores 5=good, 3=acceptable, 1=poor *P<0.05

Source of Information: Gim,N.G and Lin, Khor (1978).

Gim N.G and Lin, Khor , also concluded that the dough prepared with an increase level of cassava flour was found to reduce water absorption, development time and stability of the dough resulting in increased dough softening or weakening. Moreover, higher levels of substitution with cassava flour increased dough extensibility, and reduce susceptibility to analyze activity, resulting in a more viscous dough. They concluded that the use of winged bean flour improved bread characteristics. It was found that up to 30% substitution with cassava flour and 5% fortification of with wean bean flour (75-20-5) yielded acceptable loaf volume, specific loaf volume and organoleptic characteristics

2.2 Nutritional Value of Cassava Flour

Cassava is a good and cheap source of Carbohydrates. After sugarcane, is considered the highest producer of carbohydrates among crop plants. It has been reported that cassava can produce 250 x 10^3 calories/ha/day compared to 176 x 10^3 for rice, 110 x 10^3 for wheat, 200 x 10^3 for maize and 114 x 10^3 for sorghum (Okigbo, 1980). However, it has low levels of protein, vitamins and mineral content. In addition to this, it has a lack of Sulphur containing aminoacids such as methionine (Balagopalan, et,al.,1992 cited by Buitrago, Julian). Because of the low levels of proteins, vitamins and mineral content cassava is often considered inferior to maize or wheat.

The chemical composition of a fresh cassava root is as followed: water 62 to 65 percent, total carbohydrate 32 to 35 percent, protein 0.7 to 2.6 percent, fat 0.2 to 0.5 percent, fibre 0.8 to 1.3 percent and ash 0.3 to 1.3 percent (Kay, 1987 cited by Wenham, 1995).“The chemical composition of the cassava varieties varies in the different parts of the plant, and according to variety, location, age, method of analysis, and environmental conditions” (Okigbo, 1980). The peel of cassava roots contains slightly more protein than is found in the flesh. The peeling process for cassava flour for human consumption results in the loss of a valuable part with a high presence of protein levels (Agudu, 1979 cited by Buitrago, Julian 1990). Please refer to Table 2.3.

Table 2. 3: Chemical Composition of Cassava Flour

Components	Root with Shell Content (%)	Root without Shell Content (%)
Dry Matter	100.00	100.00
Available Carbohydrates	83.80	92.40
Crude Protein	3.05	1.56
Ether extract	1.04	1.56
Ash	2.45	2.00
neutral detergent fiber	6.01	3.40
Acid detergent fiber	4.85	1.95
Hemicellulose	1.16	1.45

Source: Agudu.1979 cited by Buitrago, Julian 1990.

Even though Cassava flour has not a high level of protein it can be used to substitute for wheat flour in producing good composite bread properties and with cereals such as maize to produce weaning mixtures, which will ensure food security.(Lyimo et al., 2007). Lyimio, evaluated the nutritional value of the following composite flours: Cocoyam: wheat: Soybean (50:20:30), Cassava: wheat: soybean (50:20:30), and Sweet potato: wheat: soybean (50:25:25). Please refer to following table.

Table 2. 4: Nutrient Composition of composite flours for baking (in dry basis).

	%				mg/100gr				
Composite Flour	**Crude Protein**	**Crude fiber**	**Crude fat**	**Carbohydrate**	**Ash**	**Ca**	**Mg**	**P**	**Fe**
Cocoyam:wheat: soybean (50:20:30)	13.26a	2.04a	2.73b	70.98c	2.64 a	320 b	150 b	460 a	15.20 a
Cassava:wheat:soybean (50:20:30)	9.96 C	1.92 B	2.83 a	74.11 a	2.51 b	320 b	150 b	430 b	15.00 a
Sweet potato:wheat: soybean (50:25:25)	12.22b	1.66 C	2.57 C	72.78b	2.51 b	330 a	190 a	390 c	14.30 a

Source: Lyimo et al.,(2007).

The cassava, wheat and soybean combination had the highest level of carbohydrate but the lowest percentage of protein. Lyimo, concluded that " formulation of composite flour of root and tubers such as cocoyam, cassava, and sweet potato up to 50% with cereals (wheat and maize) and legumes (such as soybeans) are good source of carbohydrate, therefore, they may be adopted as an alternative and cheap source of energy for most people".

According to Grace (1977), a research on the nutritional value on composite flours was assessed in 1965 by the Central Institute for Nutrition and food Research, (Utrecht, and Zeist). In this research the nutritional value of cassava and soya bread and cassava groundnut bread was compared with the protein quality of common wheat bread. It was concluded that the protein quality of both breads was higher than that of common wheat bread. "The cassava soya bread topped the other two breads in protein quality, while the cassava/groundnut bread was slightly superior to common wheat bread".

From the nutritional point of view, the protein quality of both the cassava-soya and the cassava-groundnut breads was higher than that of common wheat bread. On the other hand, "Food habits are primarily based on socioeconomic and other conditions rather than on scientific considerations. Changes in established habits can take place gradually through public education and the spread of knowledge". (Grace,1977).

2.3 Food Safety Aspects of Cassava

There are two different cyanogenic glucosides present in cassava roots, linamarin and lotaustralin. Linamarin accounts for 95% of the total of cyanogen content and it is present in all tissues (Balagopalan et al., 1988 cited by Oke 1994). The presence of cyanogenic glucosides in cassava roots can be harmful for the consumer. “At the harvest of cassava roots, the amount of the acid in the plant varies from harmless to lethal - from a few milligrams to 250 milligrams or more per kilogram of fresh root”.(Grace, 1977). However, “more than 95% of cyanogenic glucosides is removed when roots are crushed and sun dried”.(Oke,1994). For this reason the high presence of cyanogens in cassava roots is due to the poor processing of cassava roots. According to Oke, in order to make cassava safe for human consumption it is required to remove the glucosides or inactivate the dhurrin B-glucosidase enzyme which resides almost exclusivelly in the mesophyll tissue, or both. The inactivation of the enzyme is not the best method because the human gastro-intestinal tract may contain micro-organisms capable of hydrolyzing linamarin which causes some level of toxicity.

The different processes to remove cyanogens from cassava roots are; Grating, Hydrolysis, fermentation and dehydration. According to Oke (1994), grating was found to be very effective through bringing the enzyme and the substrate together intimately. The hydrolysis which results in the decrease of the pH from 6.0 to 3.8 is favored at the beginning with high pH to remove cyanogens but un-favored at low levels of pH. For this reason hydrolysis must be mixed with different methods in order to eliminate all the cyanogens. The fermentation of cassava roots is considered one of the most effective techniques to remove the cyanogens. According to Oke (1994), there are two types of fermentation aerobic and anaerobic. The most common is aerobic, when the peeled roots are soaked into water for several days, the micro-organisms in the roots ferment the soluble carbohydrates (sugars) to form lactic acid and some acetic acid, reducing the ph from 6.0 to 3.5 after 5 days. “The fermenting micro-organisms cause softening of the pulp reducing the cyanogens level to insignificant levels through microbial decomposition” (Oke,1994).

The dehydration process results in the elimination of the glucosides since cyanogenic glucosides are soluble. The dehydration process can be achieved in different ways: A) By pressing out the water using hydraulic press, B) By heating the cassava roots.

The heating of cassava roots can be by the use of artificial driers or sun drying. Please refer to the following chart to see the effect of drying process on cyanogens content of cassava.

Table 2. 5: Effect of drying process on cyanogens content of Cassava

Drying Process	Cassava type	Residual Cyanogen content (mg HCN equivalent Kg-1).
Freeze drying	(pulp)	439
Flash drying	(slices)	432
Air drying 40 C	(Chip, pulp)	13
Heated air drying 180 C	(Chips), (Fermented pulp)	77
Drum drying	(pulm) (fermented pulp)	121
Total Cyanogen Content of Pulp		900

Source: Meuser and Smolink, 1980 cited by Oke 1994.

Oke, finally concluded that traditional methods of cyanogen removal from cassava are very efficient. When cassava is peeled and grated before fermentation and then combined with sun-drying or moderate heat, it is possible to obtain a cyanogens-free product, irrespective of the variety of cassava used. For this reason, cyanide content in cassava flour will not be a problem when following traditional processing methods.

The different processes involved in the processing of roots into High quality cassava flour are: raw material selection, peeling, washing, grating, pressing, disintegration, sifting, slicing and shipping, drying, milling, screening and packaging and storage. (Dziedzoave, et al.,2003). Please refer to following pages to see the quality parameters and flow process diagram.

Table 2. 6:Objective Standard Specifications for High Quality Cassava Flour

Quality Parameter	Specification	Unit Processes & other factors impacting on quality specification
Moisture (%)	8-10	slicing/grating, drying
Color: L*	>99	slicing/grating, pressing & drying
a*	<8	
b*	<(-4)	
C	<8	
h*	>92	
Taste: Acidity (%)	<0.25	slicing/grating, pressing, drying, packaging & storage
pH	6-7	
Average Partice size (um)	115-120	milling, screening & sifting
Starch (%)	>70	slicing/grating and drying
Extraenous matter (specks/100cm2)	<10	peeling & washing
Pasting Temperature (C)	<74	Drying
Viscosity (Bu)	>750	Drying

Source: Diedzoave et al.,(2003)

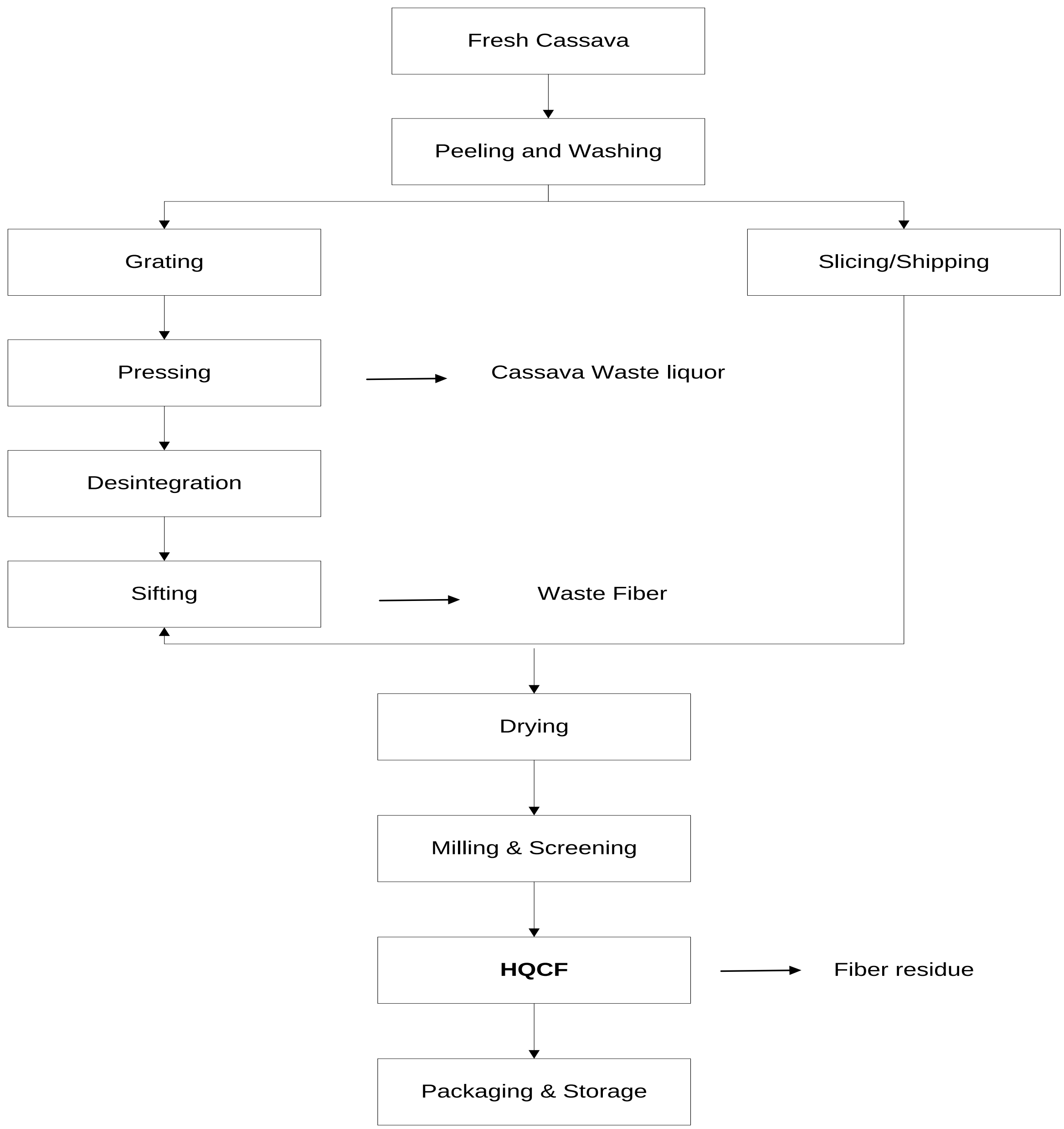

Figure 2.1: Flow Chart Cassava Flour

Source: Diedzoave et al., (2003)

2.4 Different Uses of Cassava in the World

The utilization of cassava varies according to the different regions in the world. However, the most important uses can be classified in three main groups: human consumption, animal feeds and starch and other uses. According to an investigation from FAO (2000) on the world cassava economy in the year 1994, the use of cassava for human consumption accounted for 58%, animal feeds for 25% and starch and other uses 17%. The global post harvest losses accounted for 19%.

According to the different regions in the world, Africa is the continent where cassava is still mostly used for human consumption, followed by Latin America, Oceania and Asia. Asia is the continent where cassava is mainly used for exports to the European Union where cassava chips are used for animal feeds (FAO, 2004).

In Latin America the use of cassava for animal feeds is also of great importance. In the year 1995 the use of cassava for animal feeds accounted for 47% (FAO, 2000).

During the last decades in developing countries the processing of cassava into different-sub products has become of great importance. This is mainly due to the increase of demand of cassava chips, pellets and starch in the international markets but also to the increase of food companies in developing countries. The increase of new food industries in domestic markets has created an equal or greater domestic demand than the export market.(FAO, 2004).

Besides this, cassava has a great potential to be used as a substitute of different import products (wheat flour, pastas, and animal feeds).

Lately, the use of cassava for human consumption in countries such as Brasil has been guided by the “ready to eat demand” and “convenient food’s demand”. Cassava is sold cooked for immediate consumption or pre-peeled and frozen for later preparation. For example; in Brasil cheese bread or “Pao de queijo” made of sour cassava starch is sold in fast food restaurants. Another example is the extruded chips of cassava similar to the extruded corn products which have become very popular in Europe and Latin America.

Please refer below to the different utilizations of cassava and some traditional preparations.

2.4.1 Cassava for Human Consumption

The cassava roots which belong to the sweetest varieties are sometimes eaten raw as between meal’s snack. However, in most of the cases cassava roots are cooked and then eaten . The most common method is boiling the roots or frying. The process of boiling or frying the roots helps to eliminate the prussic acid content.

Besides cooking the roots for immediate consumption, many food dishes use the cooked roots as basic ingredients to which is added a variety of other ingredients, for example; meat, fish, soybean cake, shrimps or other protein source which are prepared in different countries. Among the most important: Krubub, Ketela and fish or prawn crackers in the Far East; Sancochado, Escabeche, Seco de Carnero, Sebiche and Pachananca in South America. (Grace,1977).

The preparations of cassava for human consumption vary according to the different regions. Some of the traditional preparations are: Farinha and cassava bread (Couac), Gari, Cassava rice (landag), and Cassaripo or tucupay. Please refer below for a detailed description.

2.4.1.1 Farinha and Cassava bread (Couac)

Farinha is a granular and slightly roasted product, it is an excellent cereal eaten like rice or in combination with other foods. It is a typical product originally from Latin America which plays an important role in nutrition. The different processes involved are: Peeling, grating, pressing the rasped material, rubbing through a sieve, and heating. The pressing step is done to extract the possible poisonous juice. The pulp obtained after grating and pressing can be worked in two possible ways; it can be mixed with a little cassava pulp which has been left to ferment for three days or dried. If the pulp is continuously heated and without stirring until the mass becomes brown in one side, it becomes a solid slab. Then the solid slab in Latin America is baked at both sides and dried in the sun to produce cassava bread also known as Couac. This type of bread (couac) is known to have a very hard texture but characterized of having an excellent flavor. Usually it is eaten after being dipped in gravy.

2.4.1.2 Gari

Gari is a fermented and gelatinized dry coarse flour, popular in West Africa and a staple food in Nigeria, Ghana, Benin and Togo. (Diop and Calverley, 1998). It is a typical food especially among low income groups. The different processes involved are: peeling, grating, fermentation and pressing, sieving, frying and drying. The fermenting step helps to reduce the hydrocyanic acid at a low pH. In Africa the efforts have been directed to promote the mechanization of Gari under hygienic conditions and to fortify the nutritional value by adding a protein additive.

2.4.1.3 Cassava rice (Landag)

Landang or also called cassava rice is a very popular food in the Philippines. It is commonly used as a substitute for rice and maize.. The different processes involved are: Shredding the tubers, pressing the grated mass in a cloth until most of the juice is squeezed out, whirling the mass in a winnowing basket to form the pellets, sifting the more or less uniform size pellets, steaming the pellets and then drying for some days. According to Grace (1977), alternatively to the processes mentioned above, the tubers can be soaked into water in earthenware jars until they begin to soften. The softening of the tubers starts between five and seven days. Then, they are macerated, the fibre is removed by hand and the mass is air dried before being made into pellets.

2.4.1.4 Cassaripo or Tucupay

Cassarpio or Tucupay is a sauce obtained from the evaporation of the juice which results from the pressing of the cassava roots. It is originally from South America where there is an ancient belief that the juice contains many valuable nutrients. The different steps involved are: Peeling, grating, pressing the raw material, dry to concentrate the juice by means of evaporation and finally adding various species including chilly. The prussic acid content is destroyed while cooking. It is very popular in Brazil and West Indies.

2.4.2 Cassava as animal feed

Cassava is used as partial or full substitution of feed grains in specific rations for swine, poultry, ruminants, and other animals. Roots are cut into chips which are then dried between 2 or 3 days. The cassava chips are used by manufacturers of pellets. Thailand is one of the biggest exporters of dried cassava chips to Europe where are very common for the production of animal feeds. (Chutharractkul, Charae 2002). The cassava leaves are also use for animal feeding due to the high protein content (21) %. However, due to the presence of cyanogens the introduction in animal feeds is limited. The prospects for the use of cassava leaf products are: low level of substitution in feed formulations for monogastric animals, and used as fresh forage as protein supplement to low quality roughages in ruminant feedings.

2.4.3 Cassava starch and other uses

Cassava is the fourth source of starch after maize, wheat and potato. Starch is used for food industries and non food industries. In the food industry starch can be used as (a) directly as cooked starch food, custard and other forms, (b) thickener using the paste properties of starch (soups, baby foods, sauces and gravies, etc.), (c) filler contributing to the solid content of soups, pills and tablets and other pharmaceutical products, fee cream, etc.;, (d) binder, to consolidate the mass and prevent it from drying out during cooking (sausages and processed meats), and (e) stabilizer, owing to the high water-holding capacity of starch (e.g., in fee cream) .(Grace, 1977).

Among the most important food industries are: a) bakeries, b) confectionaries, c) canned fruits, jams and preserves, d) Monosodium glutamate (MSG) industries, and E) Caramel industries.

On the other hand starch is also used in non food industries, among the most important are: paper, textile, and furniture industries.

The processing of cassava into starch has become very important during the last years. Since the year 1980 to 1997, the global demand increased in 4.7% per year.(FAO,2000).

2.4.3.1Alcohol

Cassava roots are considered one of the richest fermentable substances used for the production of alcohol. Dried roots contain about 80% which are equivalent to rice as source of alcohol. (Grace, 1977). Ethyl alcohol is the most popular fermented substance produced from carbohydrates. The process involves, washing the roots, crushing them into a thin pulp and screened. Then adding sulphuric acid is added to the pulp in pressure cookers until total sugars reach 15-17% of the contents. Then, sodium carbonate is added to adjust the pH and then yeast fermentation is allowed for three to four days to obtain alcohol, carbon dioxide and other substances from sugar. The last process is the separation of alcohol through heat distillation. Among the different uses of cassava alcohol are; cosmetics, solvents and pharmaceutical products.

2.4.3.2 Dried Yeast

Cassava starch is used for the production of yeast for animal feeds as well for human consumption through the use in bakery products. The process involves the hydrolysis of starch into simple sugars by the use of mineral acids and enzymes. After that, certain yeasts are propagated which produce microbial cellular substances. The dry, inactive yeast contains about 7 percent moisture and the raw protein content can vary between 40 and 50 percent depending on the raw material.

According to Grace, (1977), in some conversions of starch into substances obtained yeasts can be 38-42% yield of yeast product containing up to 50 raw proteins.

3. METHODOLOGY

3.1 Study Area

This investigation was done in Nicaragua, in the municipality of Diriamba, located in the department of Carazo (11°51′N 86°14′W). The reason of doing the experiment in Diriamba was due to the accessibility to local bakeries to do the baking trials.

Diriamba is the second populated city of Carazo, with a population of approximately of 31, 200 inhabitants.

On the other hand, Nicaragua is the largest country of Central America with a total area of 130,370 km2. It is located between Honduras on the North and Costa Rica on the South, bordering both the Caribbean and Sea and the North Pacific Ocean. It has a tropical weather in lowlands and cooler in high lands. The population is 5,891,199 from which 33.8% are from (0-14 years), 62.9 % (15-64 years), and 65 years and over is 3.3 %. The population growth rate is 1.784 %.Nicaragua has the second lowest per capita income in the western Hemisphere (U$ $2900). The GDP is 16.83 billion from which 16.9% is Agriculture, 25.8% industry and 57.3 % services.

Figure 3. 1: Map of Nicaragua

Source: (CIA, 2010)

3.2 Research Design

The design of this investigation involved the search of secondary and primary information. The search of the secondary information involved a desk research strategy on: 1) the bread making potential of cassava flour as partial substitute of wheat flour. 2) the nutritional value of cassava flour and food safety aspects, 3) the different uses of cassava flour in the world.

The primary information came from, sensorial evaluations with consumers, different baking trials with local bakeries and an open interview with a processing plant manager. For the consumers two types of sensorial tests were performed (a triangle test and paired preference test). The triangle test was used to identify if there was an observable significant difference between wheat bread and wheat cassava bread. The paired preference test was used to identify if there was a significant difference in preference by the consumer between wheat bread and wheat-cassava bread. These two tests were used to identify the consumers' acceptance towards wheat-cassava bread.

The strategy used for the baking trials was a combination of experiment and interview with the local bakeries. The tests involved baking wheat- cassava bread at 10%, 15% and 20% substitution. Wheat bread (100%) was also prepared to compare the characteristics on (taste, texture, colour and volume).

The interview with the processing plant manager was mainly on the actual situation of the plants and the obstacles to produce cassava flour for human consumption. It was an open interview because there was not a fix questionnaire to follow.

The information collected from the sensorial tests with consumers was quantitative and the information collected from local bakeries and processing plants was qualitative.

This research was designed at a high level in the chain since consumers and processing plants which in this case are the potential customers, have the power in the chain. Please refer to next page to see research frame work. Under data collection there is more detailed information on the strategies used.

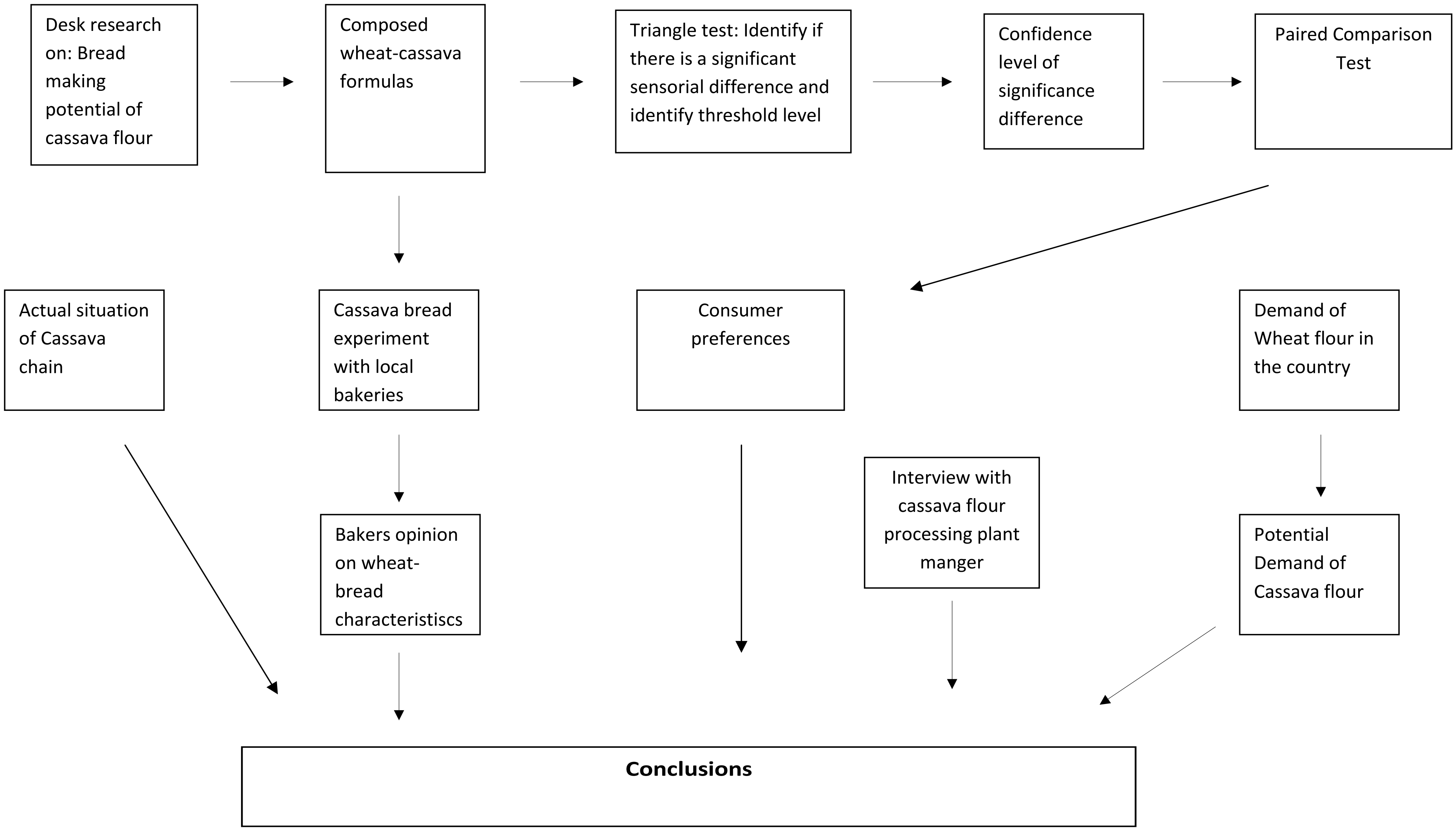

Figure 3. 2: Research Frame-Work

3.3 Data Collection

The experiment involved different baking trials, beginning with 100% wheat flour and continuing with 10%, 15%, and 20% partial substitution of cassava flour in wheat flour. The ingredients in the different formulas remain constant; the only difference was the replacement of wheat flour for cassava flour. The control sample was the 100% wheat bread and served as reference to compare the different characteristics of the wheat-cassava bread. The characteristics of the bread samples were defined according to the results of the different bread samples. No scientific parameters where used to define taste, colour, texture, volume and aroma. The description came from the opinion of local bakeries with the exception of bread height which was measure with a ruler.

To collect the information in the experiment five bakeries were invited to observe the results of the different bread samples and give their opinion on bread characteristics. The formula used in the experiment was taken from a local bakery used for the production of plain bread. Please refer to following table to see formula.

The following formula is based on a total batch of 2246 grams.

4 Table 3. 1 Wheat bread base formula

Ingredients	Grams
Wheat flour	1362
edible palm oil	57
Margarine	57
Sugar	114
Yeast	45
Salt	15
Water	596
Total	2246

5 Source: Field Research 2010

The reasons to make the formulation on a total batch of 2246 grams was because of the availability of 1362 grams (3lbs) bags of wheat flour in the market. The substitutions of cassava flour were according to the different percentages (10%, 15% and 20%) on the wheat flour. The corresponding percentage of wheat flour was taken out from the formula and added with cassava flour. The cassava flour was prepared by the Tecno-Agro processing plant from a sweet cassava variety called “Ceiba”. The different processes involved in the cassava flour preparation were: Peeling, washing, manually chipping the roots, sun drying for 4 days, milling, and sieving through a 250 Um-mesh sieve.

3.3.1 Sensorial Tests

3.3.3.1 The triangle test

The triangle test was used to analyse if there was a significant sensorial observable difference between wheat bread and wheat-cassava bread. The reason why the triangle test was chosen is because it is an analytical sensorial test used to detect whether or not a detectable difference between two similar samples exists.

For that a hypothesis was developed; H_0= There is no sensory observable difference between wheat bread (A) and composed wheat-cassava bread (B). And, H_1=there is a sensory observable difference between wheat bread (A) and wheat-composed bread (B).The hypothesis "H_1" is only accepted if there is confidence level higher than 95% so p= <0.05%.

The panellists chosen were regular consumers, not trained panellist. Thirty consumers were required per each test; therefore 30 answers were given per test. The criteria to choose the panellists was based on the age (X >15) and gender; at least 40% men will be required and 60% women. This was because during the week days men are working and women usually stay at home.

The materials used per test were; 90 small size sample breads (45 composed bread and 45 wheat bread), 30 plastic cups of water and 30 answer sheets for the panellists.

One boot was built for the panellist to test the samples so one panellist could do the test at time. The boot had colour lights so consumers were not able to identify the different sample by bread colour. Please refer to Appendix C to see picture.

The procedure used was the following:

Each panellist received 3 types of bread according to the different combinations (ABB, BAA, AAB, BBA, ABA, and BAB). The letter "A" represents wheat bread and the letter "B", wheat-cassava bread. Each bread had a code and they were prepared according to the different combinations. Each panellist had to try once a piece of bread from left to right and drink a sip of water in between the different bread samples. For the case of 15% and 20% substitution, the volume of bread went down and thus it was easily recognizable. Therefore, instead of using 20% it was decided to use 17% substitution which was more similar to 15% .

Due to the decline in bread volume, in the case of 15% substitution, the wheat bread had to be pushed down so the bread samples looked the same. For the case of 17%, consumers were bent with a handkerchief and the bread was cut in two pieces of the same volume to avoid easy recognition from consumers. Please refer to Appendix A and B to see pictures of bread samples.

The bread samples had unique codes. If wheat bread (A) was presented two times the corresponding codes were; A = 224, 572 and B = 347. On the other hand if wheat-cassava bread (B) was presented two times, the corresponding codes were A= 325 and B = 485, 723. Please refer to Appendix C and D to see the proposed plan with all the different combinations.

3.3.1.2 The paired preference test

The paired preference test was used to analyse if there was an observable significant difference in preference between wheat-cassava bread and wheat bread by the consumers. The reason why the comparison test was chosen is because it is used to compare two samples directly. In this case the wheat bread and the wheat-cassava bread.

A hypothesis was developed; H_0 = There is no sensory observable difference in preference between Wheat- Cassava bread and wheat bread by consumers. And, H_1 = There is a sensory observable difference in preference between wheat-cassava bread and wheat bread by consumers. The hypothesis "H_1" is only accepted if $p= <0.05\%$. The panellists chosen were the consumers. Thirty panellists were required by test; therefore thirty answers were received by test. The materials used were; 60 small sample breads (30 wheat breads and 30 wheat-cassava breads), 30 plastics beakers of water, and 30 answer sheets. The same boot for the triangle test was used.

Each panellist received 2 types of bread, one wheat-cassava-bread and one 100% wheat bread. The samples were coded as following: A = 592 = Wheat-Cassava bread and B = 349 = Wheat bread. Please refer to appendix F and G to see proposed plan and answer form.

3.4 Data Analysis

The tools to analyse the quantitative data were; two sensory evaluation tables from the book "Sensory Evaluation techniques" for the triangle test and paired preference tests (Please refer to the appendix H and I) and the SPSS analytical software to process the data. The qualitative data was analysed according to the different answers from the interviews related to the results of the experiment with the bakeries. A consolidation of the most relevant points is summarized in the results chapter.

3.5 Ethical Considerations

To ensure the well execution of sensorial tests all the measures were taken for the accuracy of the results. In the case of the triangle test, all the procedure was followed to avoid the 9 possible errors (expectation, stimulus, logical, leniency, positional bias, contrast and effect and convergence, central tendency, and motivation error). (Postel et al.,1991) . Please refer to appendix K to see more details.

To make panellists feel at ease in the triangle test, they were given the basic instructions without saying anything about the types of the sample breads. Moreover, it was said to them that no correct answer existed and that all the answers were valid. This helped to reduce pressure on the panellists.

For the testing area, a boot was built; this means that one panellist was passing at a time to do the test. In this way the panellists were alone when filling the answer forms without having any pressure from people around. After each panellist finished the test, it was not allowed to go back to the waiting room in order to prevent panellists sharing information with each other's.

In each of the triangle tests the panellists were different to assure the validity of the answers. The data was not processed during the tests in order to prevent any expectation from the panellists on the results. For the case of the triangle test with 17% substitution of cassava flour on wheat bread, the panellist had to be bent on their eyes with a handkerchief and the different bread samples cut into small pieces and pressed down so the different samples had the same volume.

The paired preference tests were carried out in two different neighbourhoods (Santa Clara and Las Esquinas) in the municipality of San Marcos. This was to ensure any people from knowing about the preparations of the two types of bread in the bakery. In the same way of the triangle test a boot was prepared, one panellist passing at a time and were not allowed to go to the waiting room to avoid panellists sharing information with each other. The panellists were provided just with the basic information; therefore the panellists did not have any information on the ingredients of the breads.

4. RESULTS

4.1 Sensorial Evaluation tests

4.1.1 The triangle tests

Three triangle tests were made with 10%, 15% and 17% substitution of cassava flour on wheat bread. The use of 17% substitution was due to the low volume of the (80-20%) wheat-cassava bread. Each of the substitutions was compared with wheat bread (100%) to see if there was an observable sensorial difference between the two. For this, each of the panellists received three bread samples according to the different combinations (ABB, BAA, AAB, BBA, ABA, and BAB). "A" represents wheat bread and "B" wheat-cassava bread. Please refer to appendix H.

In each of the tests, 30 panellists participated; therefore 30 answers were given per test. The results were analyzed according to table 17.8 in appendix F. Please refer below to see results.

4.1.1.1 Wheat-cassava bread (90-10%) and Wheat bread (100%)

Hypothesis:

H_0 = There is no sensory observable difference between wheat-cassava bread (90-10%).and wheat bread (100%).

H_1 = There is a sensory observable difference between wheat-cassava bread (90-10%) and wheat bread (100%).

Results:

Table 4. 1Triangle test (10%) substitution

Number of Panelists	Correct answers	Wrong answers
30	10	20

According to table 17.8 in appendix H, 16 correct answers are required to reject H_0. Therefore, H_0 is not rejected but accepted. For this reason it is concluded that there is no sensory observable difference between wheat- cassava bread (90-10%) and wheat bread (100%).

4.1.1.2 Wheat-cassava bread (85-15%) and Wheat bread (100%)

Hypothesis:

H_0 = There is no sensory observable difference between wheat-cassava bread (85-15%) and wheat bread (100%).

H_1 = There is a sensory observable difference between wheat-cassava bread (85-15%) and wheat bread (100%).

Results:

Table 4. 2 Triangle test (15%) substitution

Number of Panelists	Correct answers	Wrong answers
30	10	20

According to table 17.8 in appendix H, 16 correct answers are required to reject H_0. Therefore, H_0 is not rejected but accepted. For this reason it is concluded that there is no sensory observable difference between wheat- cassava bread (85-15%) and wheat bread (100%).

4.1.1.3 Wheat-cassava bread (83-17%) and Wheat bread (100%)

Hypothesis:

H_0 = There is no sensory observable difference between wheat-cassava bread (87-13%) and wheat bread (100%).

H_1 = There is a sensory observable difference between wheat-cassava bread (87-13%) and wheat bread (100%).

Results:

Table 4. 3Triangle test (17%) substitution

Number of Panelists	Correct answers	Wrong answers
30	19	11

According to table 17.8 in appendix H, 16 correct answers are required to reject H_0. Therefore, H_0 is not accepted but rejected. For this reason it is concluded that there is a sensory observable difference between wheat- cassava bread (83-17%) and wheat bread (100%).

4.1.2 The paired preference test

Two paired preference tests were made between wheat-cassava bread at 17% and 20% substitution and wheat bread. The reason to use 17% cassava flour substitution for the paired preference test is due to an adjustment made in the triangle test because of the low volume of (80-20%) wheat-cassava bread as well as changes on texture.

The results of the triangle tests showed that there is a significance difference at 17% that is the reason why the (83-17%) is compared.

The paired preference test was used to analyze if there was significant difference in preference from the consumer between wheat bread and wheat-cassava bread. The panellists received two bread samples according to the two possible combinations (AB and BA). "A" represents wheat bread and "B" represents wheat-cassava bread. Thirty panellists participated on the tests which mean that thirty answers were given per test. The data was processed with SPSS software (Statistical package for the social science) and table 17.12 in appendix I was used to compare results.

4.1.2.1 Wheat-cassava bread (83-17%) and Wheat bread (100%)

Hypothesis:

H_0 = There is no sensory observable difference in preference between wheat-cassava bread (83-17%) and Wheat bread (100%) by consumers.

H_1 = There is a sensory observable difference in preference between wheat-cassava bread (83-17%) and wheat bread (100%) by consumers.

Table 4. 4Paired preference test: (17%) substitution

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Asymp. Sig. (2-tailed)
Preference	Group 1	Wheat bread	13	,43	,50	,585[a]
	Group 2	Wheat-Cassava bread	17	,57		
	Total		30	1,00		

a. Based on Z Approximation.

Due to the fact that the value of Asymp. Sig.(2-tailed) is higher than 0.05, then it is concluded that there is no sensory observable difference in preference between wheat-cassava bread (83-17%) and wheat bread by consumers. According to table 17.12 in appendix I, at least 21 panelists have to prefer the same sample bread two conclude that there is a significance observable difference in preference between wheat-cassava bread and wheat bread. Therefore, H_0 is not rejected but accepted.

4.1.2.2 Wheat-Cassava bread (80-20%) and Whet bread (100%)

Hypothesis:

H_0 = There is no sensory observable difference in preference between wheat-cassava bread (80-20%) and wheat bread (100%) by consumers.

H_1 = There is a sensory observable difference in preference between wheat-cassava bread (80-20%) and wheat bread (100%) by consumers.

Table 4. 5 Paired preference test: (20%) substitution

Binomial Test

		Category	N	Observed Prop.	Test Prop.	Asymp. Sig. (2-tailed)
Preference	Group 1	Wheat bread	10	,33	,50	,099[a]
	Group 2	Wheat-Cassava bread	20	,67		
	Total		30	1,00		

a. Based on Z Approximation.

Due to the fact that the value of Asymp. Sig.(2-tailed) is higher than 0.05, then it is concluded that there is no sensory observable difference in preference between wheat-cassava bread (180-20%) and wheat bread.According to table 17.12 in appendix I, at least 21 panellists have to prefer the same sample bread to conclude that there is a significance observable difference in preference between wheat-cassava bread and wheat bread. Therefore, H_0 is not rejected but accepted.

4.2 Results of the baking tests

The experiment with the local bakeries involved the substitution of cassava flour into wheat flour at levels of 10%, 15% and 20%. The base bread (100% wheat bread) was prepared as reference to compare bread characteristics. The ingredients used in the different formulations remain constant; the only variation was the substitution of cassava flour. The methodology used for the definition of bread characteristics was a group interview with 5 bakeries on the bread characteristics according to the different bread samples of the baking tests.

The following characteristics of bread were observed and agreed by the local bakeries.

1. It was visible that the wheat-cassava bread samples (10, 15 and 20%) were more brownish in colour than wheat bread, especially in the internal part of bread. The wheat bread was brown on the top external layer but white in the internal part. (Please refer to appendix A to see pictures). It was concluded that there is a relation in the substitution of cassava flour with the external and internal colour of bread.

2. The texture of the external surface of the wheat-cassava breads was porous and not smooth as the 100% wheat bread.

3. The wheat-cassava bread was described as more solid than wheat bread. On the other hand, the wheat bread was described as light and spongy.

4. There was more water absorption from the wheat dough compare to the composed dough.

5. The difference on taste between wheat bread and wheat cassava bread was described as minimum. However, wheat-cassava bread was described as more aromatic than wheat bread.
6. The volume of bread decreased as the substitution of cassava flour increased. The height of the different bread samples was measure. The height of wheat bread (100%) was (5 cm), (3.8 cm) for (90-10%) wheat-cassava bread, (3.5cm) for (85-15%) wheat-cassava bread, and (2.9 cm) for (80-20%) wheat-cassava bread. Please refer to appendix B to see pictures.

4.3 Opinion of bakeries on results

The following conclusions come from the most relevant comments of bakeries on wheat-cassava bread characteristics.

1. The decline of volume was seen as a negative characteristic since it affects the external appearance of bread. As one baker said “consumers and retailers might claim that we are using fewer ingredients for the preparation of bread and might influence the price of bread”. Another baker said “we try to produce low cost and high volume bread since the retailers are interested in low cost bread”.
2. The slightly difference on texture, especially at 15% and 20% substitution was seen as positive, as one baker said “It’s similar to a bread very popular in Nicaragua in which the

dough is prepared by hand and as a result the texture becomes more porous and it is more solid". However, they were concerned on the shelf life of that type of bread, since the bread prepared by hand has a lower shelf life than wheat bread prepared with machine.

3. The taste was seen as positive characteristic because it does not vary a lot compared to wheat bread.
4. For colour, all bakers agreed that brown colour on bread is seen more nutritional by consumers, and it is usually more expensive than common wheat bread.

4.4 Results of the interview with processing plant manager

The interview was held in Nicaragua with the General Manager of Tecno-Agro, a private company involved in the production and commerce of tubers. The reason of selecting this company for the interview is because it has three cassava processing plants.

The main questions of the interview were related to the actual situation of the plants and relation with producers, the opinion on the development of a potential market with local bakeries, and the main obstacles or points of considerations that need to be taken into account for the potential development of a project of such a kind. Please refer below to a summary on the key points of the interview.

4.4.1 Actual Situation of cassava flour processing plant

Tecno-Argo principal activity is the exports of fresh cassava for the export market (United States, Puerto Rico, and Central America). Cassava flour is used for animal production. The prices for cassava flour for animal production are low. The prices fluctuate during the year between (12-16 US) per 50 kg bag for final product. The prices paid to producers are between (2-3 US) per 50 kg sacks since three sacks are required to make one of final cassava flour.

Tecno -Agro has formal relations with some groups of producers in the plant located in the municipality of Leon on the West part of the country. The formal relation is done through the help provided to producers for getting loans from the bank and being liable as co-owner for the production areas. The Millennium Challenge Cooperation from the United States of America has some projects in the municipality of Leon with cassava producers; the main objective is to promote the associativity between different stakeholders in the chain. This program has contributed to the alliances developed by Tecno-Agro with cassava producers.

The company also works with producers who do not have formal relations. These types of cassava producers do not constantly supply the plant, just in certain occasions depending on harvest seasons.

4.4.2 Opinion of processing plant manager in supplying local bakeries

The potential development of a new market for cassava flour is of great importance for the cassava chain in Nicaragua. The prices of cassava flour in the feed industries are low and producers are not getting high prices. If a high price can be obtained from the cassava flour from local bakeries it is a market alternative that all cassava processing plants will be interested. If the prices of cassava flour increase, all the stakeholders can benefit.

4.4.3 Obstacles in producing cassava flour for local bakeries

1. The companies in Nicaragua do not count with the equipment for the processing of cassava flour for human consumption and artificial driers for rainy season.

2. Local bakeries require a constant demand of cassava flour with good quality.

3. There are price fluctuations on cassava and wheat during the year.

4. Potential unwillingness of Wheat millers to form a strategic alliance with cassava flour processing plants.

5. DISCUSSION

5.1 The sensorial tests

According to the results of the different triangle tests, there is no significant difference between wheat-cassava bread at 10% and 15% substitution and wheat bread, which means that there is a great opportunity for introducing cassava flour as partial substitution in wheat bread for the domestic market. These results are similar to the ones held by Eddy et al, on a sensory evaluation of wheat-cassava composite breads and effect of label information on acceptance and preference:

"Although the proximate composition of the composite breads was slightly different from that of 100% wheat bread, it has been found out that bread baked with 10 and 20% composite flour was not significantly different in mot sensory attributes, acceptability and readiness to buy from the control". (Eddy et al., 2007)

However, the results of the triangle test with 17% substitution in this research showed that there is a significant sensorial difference due to the fact that there was confidence level higher than 95%. This result differs from the one of Eddy in which up to 20% substitution it found no significant difference.

The results of the two paired preference test between wheat-cassava bread at 17% and 20% substitution and wheat bread, show that there is not an observable difference in preference between wheat-cassava bread and wheat bread by consumers. This is an opportunity for the wheat-cassava bread because consumers have not a preference on wheat bread which in this case is the bread that has been in the market for many years. It is for this reason that it was concluded that there is a good acceptance from consumers towards wheat-cassava bread.

On the other hand, there was a tendency from the panellists to choose the wheat cassava bread over wheat bread. In the first paired preference test, (57%) of the panellists preferred wheat cassava bread (83-17%) over wheat bread and in the second preference test, (67%) of the panellists preferred the (80-20%) wheat cassava bread over wheat bread. However, the number of panellists did not reach a confidence level higher than 95%.

According to Eddy et al., (2007) in his work on the wheat composite breads sensory evaluations, there was a tendency for bread baked with 10% and 20% cassava flour to be rated higher than the control, especially in flavour, acceptability and desire to buy.

Moreover, Gim, N and Lin Khor (1978), in their work on the use of cassava and winged bean flour in bread making, concluded that (90-10%) wheat cassava flour bread was rated higher in crust colour, crust toughness, crumb colour, crumb texture and flavour than wheat bread.

From the results discussed above it is concluded that from the consumers point of view there is a good opportunity for the introduction of wheat-cassava bread in the domestic market.

5.2 Experiment with Local Bakeries

The major concern of the bakeries on wheat-cassava bread was on the decline in volume. The low volume affects the appearance of bread and can influence the consumer's perception of quality towards wheat-cassava bread. As they explained, a lower volume in bread can be related by consumer to the use of fewer ingredients for the production of bread. However, in the results of the comments of the two paired preference tests, panellists who selected either wheat bread or wheat-cassava bread as the most preferred sample were not concerned on volume of bread. Most of the comments why they preferred a bread sample were on taste and texture. From all the comments of the panellist reviewed from the paired preference test, there was none in which the consumers preferred a bread sample because of volume. From this it is concluded that the perception of volume of bread of quality from bakeries is not the perception of bread quality for consumers. On the other hand, bakeries do not sell all their bread directly to consumers but also to retailers (small shops). According to the local bakeries the interest of most of the retailers that work with artisanal bakeries is on cheap bread with a good volume. Therefore, the fear of local bakeries on bread volume is more related to supply retailers and not final consumers. However, the power of the demand relies on the consumers and not in retailers. From this reason the volume of bread is not an obstacle for the introduction of wheat-cassava bread into the local market.

The good acceptance by local bakeries on most of the bread characteristics (taste, texture, color and aroma) do not differ from the investigations of Defloor (1995), on the bread making potential of cassava flour. As he concluded: "the decrease of loaf volume was more remarkable than bread properties". The conclusion of the experiment with the bakeries on the different baking trials was that there is a direct relation between the increase of cassava flour and decrease in volume. (Please refer to appendix B to see pictures).

According to an investigation on cassava flour as partial substitution of wheat flour by the Federal Institute of Industrial Research in Oshodi (2005), cassava flour can successfully be mixed with wheat flour for bread between 10-15% which most accepted for bread making and 15-20%, being most accepted for confectioneries and other baked products. Among the other baked products are biscuits and cakes which do not require a high volume. The results of the institute of Industrial research of Oshodi acknowledges the better potential of cassava flour at substitution of 15% and 20% substitution in low volume baked products. In the results of the experiment with the bakeries the bread samples of 15% and 20% substitution of cassava flour had the lowest volume. Therefore, the use of 15% and 20% of cassava flour partial substitute in confectionaries and other low volume bake products can be good alternative.

5.3 Interview with processing plant manager

From the results of the interview with the manager of Tecno Agro, it can be concluded that the prices they are paying to cassava farmers per 50 Kg bags (2 to 3 US) are low as well as the prices they receive for cassava flour (12-16US). On the other hand, the prices of wheat flour per 50 kg bags that bakeries are currently paying (34 to 37U$) are higher than current prices for cassava flour for the animal feed industries. This is an opportunity for the development of a new market channel for cassava flour that could generate value to the existent chain.

An estimate on the potential price of cassava flour made by the manager of Tecno Agro is 30 U$ per 50 kg bag. This means at least 15% reduction in price compared to wheat prices. However, further research must be done in cassava and wheat price fluctuations during the year to estimate the potential benefits during different seasons of the year.

According to an investigation from FAO publication (1995), on a global market study of cassava, "the major economic development of substituting cassava flour into wheat flour is the rising cost of wheat against the potential to produce cassava flour at lower price". The results of several production trials from FAO in Ghana showed that cassava flour was produced between US$0.13/kg and US$0.22/kg depending on the drying method; sunlight or artificial driers compared to wheat flour price of US$1.30/kg. An example of the potential savings for local bakeries in the FAO publication is an analysis of biscuit costs when cassava flour was substituted. "Small bakeries in Ghana were using 0.5 kg of wheat flour per kilo of biscuits, ending with a wheat flour cost of US$0.65. When cassava flour was used as substitute of 35% of the wheat flour, a cost saving of 32% was achieved". (FAO, 1995)

The results of the investigations of FAO show that cassava flour can be produced and offered to the market at very competitive price compared to wheat and can contribute to cost reduction to bakeries. However, the setting of cassava flour must be carefully formulated.

The setting of the cassava flour price must be guided by two aspects: to offer a competitive price for cassava flour compared to wheat flour in the local markets and, to set a price that can generate value to the different stakeholders of the chain. The setting of too low prices might affect the perception of quality for cassava flour from bakeries and consumers. Moreover, if the cassava farmers get low prices the supply to the processing plant can be affected. This is an issue related to the sustainability of the chain and especially on the profits of the different stakeholders that must be highly considered.

Among the main obstacles discussed in the interview with the processing plant manager in supplying local bakeries with cassava flour were; the lack of equipment for processing cassava flour for human consumption, the constant demand of local bakeries for cassava flour, constant cassava quality demanded, cassava and wheat price fluctuations and the possible unwillingness of wheat millers to make a strategic alliance with cassava flour processing plants to produce wheat-cassava flour in large scale for the market.

Regarding the lack of equipment for processing cassava into flour for human consumption the FAO, CIAT (International Centre for Tropical Agriculture) and the institute of tropical Agriculture (IITA) have worked on development of technologies for the processing of cassava flour for human consumption. According to the proceedings of a small group meeting in Nigeria (2005), on the analysis of the status of cassava food sub-sector, (IITA) developed a simple process of producing high quality cassava flour suitable for baking. The equipment involved a peeler, a pelletizer, hydraulic press and a flash drier. The equipment was designed for small famers since in Nigeria cassava is primarily grown by small farmers. It was concluded that since cassava is highly perishable plants must be as close as possible to plantations to avoid transporting over long distances. This involves the opportunity to create many small processing plants over the country.

In Nicaragua, cassava is also primarily grown by small producers therefore the equipment developed by (IITA) suits for Nicaraguan situation. On the other hand, the cassava flour processing plants have equipment to process cassava into flour for animal consumption. It will be required to do an evaluation to see if some of that equipment could be used for the processing of cassava into flour for human consumption. This could reduce the investment costs.

In the case of the constant demand from local bakeries on cassava flour, it is necessarily to know the actual production of cassava in Nicaragua as well as the potential demand for cassava flour from local bakeries.

According to the latest report from FAO statistical centre in 2008, Nicaragua production of cassava was 115,000 tons. On the other hand, the International trade centre reported that the wheat imports of Nicaragua in 2008 were 97,967 tons. This means that there is more production of cassava than wheat imports. However, according to FAO (2004), one ton of cassava flour requires four tons of fresh cassava tubers. With this information it can be calculated the amount of cassava required for the partial substitution of cassava flour in wheat flour at a national level.

If 10% (9796.7) of wheat flour is assumed to be replaced with cassava flour, then four times the 10% of wheat flour imports (39,186 tons) are required. The 10% substitution of wheat cassava flour with cassava flour represents 34% of total production of cassava flour in the country. With this numbers it can be concluded that there is availability of cassava produced for the replacement of 10% of wheat flour. However, to figure out the exact quantities of cassava available, is necessary to know the post-harvest losses which are usually high in developing countries of cassava and the demand of cassava for other marketing channels.

The Nicaraguan Agricultural Census (CENAGRO), in 2001 reported that 70% of Nicaraguan production is in the Atlantic Coast and 30% in the Pacific coast especially mainly in the department of Masaya and Leon. (IICA, 2004), contrary to the case of local bakeries in which 90% are located in the Pacific Coast and 10% in the Atlantic Coast. (Ministry of Economy of Nicaragua 2003). The transport of cassava flour from the Atlantic Coast of Nicaragua to the Pacific Coast raises the costs. This is a point of consideration to be taken when thinking on a potential national project on the partial substitution of cassava flour in wheat flour.

However, an initial intervention in the processing of cassava flour for local bakeries should start as a “pilot project” in a specific region of the country where there is enough cassava cultivated to meet demand. The development of a national project requires time and more analysis on production planning according to demand to offer constant competitive prices.

The aspect of supplying cassava flour of good quality is of great importance because is a direct factor that influences potential demand. This issue was also discussed in the proceedings in Nigeria in 2005 on the analysis of the status of cassava food sub-sector. The conclusion is that cassava flour must comply with national required standards if they exist, if not quality standards must be defined with the institutions in charge of food regulation in the country according to the international standards such as ISO (International Organization for standardization) and Codex guidelines to assure food safety and quality to local bakeries. This aspect requires the further investigation for the processing of cassava flour for human consumption in the country.

The case of price fluctuations of cassava and wheat is an important issue since one of the possible competitive advantages of cassava flour over wheat flour could be cost leadership. This is because cassava can be produced locally. As it was mentioned before by FAO, the major economic development of substituting cassava flour into wheat flour is the rising cost of wheat against the potential to produce cassava flour at lower price. Further analysis will be required on price fluctuations and government subsidies in the case of wheat producing countries.

The final aspect discussed in the meeting was a potential obstacle which is the unwillingness of wheat millers to develop a strategic alliance with cassava flour processing plants. This is because using cassava flour as partial substitute could means less imports of wheat for wheat millers. Therefore, wheat millers are the stakeholders who could be affected in this change on the chain.

However, a potential alliance between wheat millers and cassava flour processing plants can become a win-win situation for both parties. For wheat millers, the partial substitution of cassava flour can help them to have more control on external wheat price fluctuations and maximize sales. The demand for bread is not inelastic in the country. This means that when the prices of bread increase, there is a decrease of demand because of the availability of substitute products such as “tortilla” made of maize. Moreover, if the price of cassava flour is more competitive than wheat flour they can have better margins of return. This will depend to some extent to the effect of external price fluctuations on wheat flour sales in the domestic market and the consumer’s acceptability towards wheat-cassava bread. If wheat-cassava bread is preferred over wheat bread and it is cheaper the consumption can also increase.

The other option for cassava flour processing plants is supplying cassava directly to local bakeries. Even though they will not reach large economies of scale they can centralized to specific regions of the country. In addition to this, by supplying 100% cassava flour to local bakeries, bakeries will have more flexibility to use it for different breads. Then, the flexibility can encourage bakeries to try different recipes and innovate.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This investigation emphasized on the consumer acceptance towards wheat cassava bread, the opinion of local bakeries on wheat-cassava bread characteristics and the opinion of cassava flour processing plant managers in the possibilities to process cassava flour for local bakeries.

The methodology involved the use of sensorial tests with consumers (triangle and paired preference test), interview and experiment with local bakeries and an interview with a processing plant manager.

From the overall findings it is concluded that there are good opportunities for the integration of cassava flour in wheat bread in Nicaragua.

The opportunities identified from the evaluation of the three stakeholders are:

1. There is a good acceptance from consumers towards wheat-cassava bread up to 20%, since it was found no observable difference in preference by consumers between wheat-cassava bread and wheat bread.
2. At 10% and 15% cassava flour substitution in wheat bread there is not significant sensorial difference with respect to wheat bread (100%).
3. .Most of the bread characteristics (taste, texture, colour and aroma) were seen as positive by the bakeries.
4. Cassava flour can be produced at a competitive price (at least 15% (30U$) cheaper than wheat flour (35-37U$).
5. The prices of wheat flour used for baking are high (35-37U$) compared with cassava flour animal feeds (12-16U$). Therefore, the use of cassava flour by local bakeries represents a good alternative for processing plants and cassava producers.
6. Cassava flour processing plants are willing to incur in a project to process cassava flour for local bakeries.

The main limitations identified are:

1. Lack of equipment for processing cassava into flour for human consumption.
2. The constant demand of high quality cassava flour from local bakeries.
3. Cassava and wheat price fluctuations.
4. Unwillingness of wheat millers to make a strategic alliance with cassava flour processing plants.
5. The low volume of bread at 15% and 20% substitution was not liked by the local bakeries.

Besides the findings described above, it was found in the desk research that the partial substitution of cassava flour in wheat flour is highly considered from FAO as an alternative to increase demand of cassava and reduce wheat imports. As a study in the global market study of Cassava by FAO in 2005, concluded that a list of countries (including Nicaragua) could realize at least a 20% increase in the demand of cassava, as 10% cassava flour could be replaced in wheat flour.

On the nutritional value it was found that cassava flour has a low level of protein content. For this reason in some cases the substitution of cassava in wheat flour also involves the use of other ingredients such as soybean to increase protein level. This requires further investigation.

In relation to food safety, it was found that the levels of cyanogens in cassava flour are very low even when using traditional methods. For this reason it is concluded that the processing of cassava into flour does not represent a high threat to consumer's safety.

The overall findings of this research contribute to the overall objective of this investigation which was to identify opportunities on the integration of cassava flour in wheat bread production in Nicaragua. Even though, this investigation was limited to the analysis of three stakeholders: consumers, bakeries and processing plants, it can be concluded that there are good opportunities for the use of cassava flour in wheat bread production in Nicaragua.

The partial substitution of cassava flour in wheat flour can reduce the Nicaraguan imports of wheat (108,299 tons in 2009) and wheat imports dependency, reduce bread costs, contribute on food security, and generate economic growth through the industrialization of cassava.

6.2 Recommendations

1. Among the different levels of cassava flour substitution, (10%, 15% and 20%); the 90-10% wheat bread was the most similar to wheat bread. Therefore, if a project is started the replacing level should start at 10% so consumer will not notice changes in the external appearance of bread especially in volume.
2. For the 15% and 20% will be most suitable for low volume type of breads, for example biscuits and other confectionaries.
3. The use of cassava flour in local bakeries should be promoted by doing trials with bakeries to show them the results since cassava flour is a new product for them.
4. An initial intervention should start as a pilot project in place in Nicaragua where cassava is highly cultivated.

6.3 Future areas of Research

1. Bread making potential of the different cassava varieties in Nicaragua.
2. Different levels of substitution of cassava flour in other different types of bread produced in Nicaragua.
3. Different yeasts or procedures to increase the level of wheat-cassava bread.
4. Nutritional value of wheat-cassava bread compared to wheat bread.
5. Evaluation of the different equipment available in Latin America for the processing of cassava into flour for human consumption and which equipment is more suitable for Nicaraguan cassava processing plants.

6.4 Limitations of the Thesis

One of the limitations of this investigation was on the analysis of the different characteristics of bread. The different samples of breads were baked in an artisanal oven not in a control atmosphere. This means that it cannot be 100% guaranteed that the different bread samples were baked on a constant temperature. However, it was part of the methodology to know the results of the baking bread trials in an artisanal oven because of being the most popular among bakeries.

The bread characteristics were not analysed with a scientific methodology, without having any specific measurement for bread crumb structure, keeping quality, and colour. It was done by comparing the different type of breads according to the base bread (wheat bread). Therefore, the results were more on the opinion of local bakeries than on technical parameters of the characteristics of each sample. The only parameter that was measured was volume.

The number of bakers that participated in the experiment was limited (5). It would have been better to have a larger number of bakeries. One of the reasons why this was not possible is because the owner of the bakery felt uncomfortable to have many bakeries who were competitors of him looking at his installations. A neutral place would have had been a better alternative to do the tests.

Moreover, the experiment was just on plain bread, not on the different types of bread produced by artisanal bakeries. Therefore, this investigation is limited to the use of cassava flour in the production of just plain bread, not in sweet bread or in the production of biscuits which is also an alternative.

The interview with processing plant managers was limited to one. This was due to the limited number of cassava flour processing plants. The advantage of the interview is that the company had three cassava processing plants.

Finally, the information available of the substitution cassava flour at those levels of substitution was limited. Moreover, it was not possible to find any information on the subject on the country due to the limited use of cassava flour.

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