Chapter 6
Turning Waste to Wealth: Harnessing the Potential of Cassava Peels for Nutritious Animal Feed

Iheanacho Okike, Seerp Wigboldus, Anandan Samireddipalle, Diego Naziri, Akin O. K. Adesehinwa, Victor Attah Adejoh, Tunde Amole, Sunil Bordoloi, and Peter Kulakow

Abstract In Nigeria, processing cassava for food and industry yields around 15 million tons of wet peels annually. These peels are usually dumped near processing centres to rot or dry enough to be burned. Rotting heaps release methane into the air and a stinking effluent that pollutes nearby streams and underground water, while burning produces clouds of acrid smoke. However, when properly dried, peels can be an ingredient in animal feed. Previous attempts over two decades to use peels

I. Okike (✉) · P. Kulakow
International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria
e-mail: i.okike@cgiar.org; p.kulakow@cgiar.org

S. Wigboldus
Wageningen University & Research, Wageningen, The Netherlands
e-mail: seerp.wigboldus@wur.nl

A. Samireddipalle
National Institute of Animal Nutrition and Physiology (NIANP), Indian Council of Agricultural Research (ICAR), Bangalore, India

D. Naziri
International Potato Center (CIP), Hanoi, Vietnam
e-mail: d.naziri@cgiar.org

A. O. K. Adesehinwa
Institute of Agricultural Research & Training, Obafemi Awolowo University, Ibadan, Nigeria

V. A. Adejoh
Synergos Nigeria, Maitama Abuja, Nigeria
e-mail: vadejoh@Synergos.org

T. Amole
International Livestock Research Institute, Ibadan, Nigeria
e-mail: t.amole@cgiar.org

S. Bordoloi
Amo Farm Sieberer Hatchery Ltd, Amo Byng Ltd, Awe, Oyo State, Nigeria

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in animal feed failed to yield profitable options for drying wet peels at commercial scale, but recent research suggests that cassava peels can be processed into high-quality cassava peel (HQCP) products to be used as nutritious, low-cost animal feed ingredients. The core innovation was to adopt the same steps and equipment used for processing cassava roots into *gari*, the main staple food in the country. When dried, 3 tons of wet peels yield a tonne of healthy and energy-rich animal feed, containing nearly 3,000 kilocalories per kilogram of dry matter (kcal/kgDM). Adopting this innovation at scale in Nigeria's poultry and fish sectors alone has the potential to turn approximately 3.6 million tons of wet peels into 1.2 million tons of feed ingredients capable of replacing approximately 810,000 tons of largely imported maize. The innovation has great potential to increase feed availability and lower its cost while saving cereals for human consumption, reducing the import bill, creating new business opportunities, and protecting the environment. This research was initiated by CGIAR centres and taken up by the CGIAR Research Program on Roots, Tubers and Bananas (RTB) over the past decade with strategic input from the CGIAR Research Program on Livestock to accelerate development of the innovation, and this chapter documents the potential and progress in taking this innovation to scale.

6.1 Introduction

6.1.1 Cassava as an Essential Crop in Nigeria

Cassava (*Manihot esculenta*), also called manioc or tapioca, is a major subsistence and commercial crop in sub-Saharan Africa. Nigeria is the largest producer worldwide, but many of the lessons and opportunities discussed here are applicable to other major cassava-producing countries, particularly in western and central Africa, such as Ghana, Ivory Coast and the Democratic Republic of Congo. Cassava has seen a steady increase in production, averaging 3% per year since 1995, reaching 59 million tons in Nigeria and 178 million tons in Africa (FAOSTAT 2019). Over 90% of the cassava in Africa is consumed as food and very little for industrial processing (Akinpelu et al. 2011). Once considered a subsistence or poor person's crop, cassava is rapidly becoming a commodity with many uses, supporting rural development, poverty alleviation, food security, and value addition with macroeconomic benefits (FAO 2013). Several African governments are promoting cassava to reduce cereal imports through mandatory blending of wheat flour with high-quality cassava flour.

6.1.2 The Growing Demand for Animal Feed and Potential Role of Cassava Peels

Growing population coupled with rising incomes, urbanization and a shift towards protein-rich diets is driving increased demand for meat, dairy and eggs. The demand for animal-derived protein is projected to double by 2050 (FAO 2016), and most of that added demand will come from to low- and middle-income countries (Barry et al. 2012). Between 1999 and 2030, annual meat consumption in these countries will increase from 26 to 37 kg per person, compared with an increase from 88 to 100 kg in industrial countries. Annual per capita consumption of dairy products is expected to rise from 45 to 66 kg in developing countries and from 212 to 221 kg in industrial countries. Egg consumption will grow from 6.5 to 8.9 kg in developing countries and from 13.5 to 13.8 kg in industrial countries (FAO 2011).

The growing demand for animal source food will require more feed (Thornton 2010). Global feed demand is estimated to increase 1.6 times from 1,058 million tons in 2010 to 1,693 million tons by 2050 (OECD-FAO 2013). Growing consensus exists on the tremendous environmental impact of expanding livestock production requiring more land to be brought into production to which the associated increased demand for feed is a major contributor (Willits-Smith et al. 2020). Reducing the pressure on natural resources and ecosystems calls for, among others, a more effective use of available biomass, including recycling (Garnett et al. 2015; Haberl et al. 2014; Karlberg et al. 2015; Smith et al. 2010). Turning crop residues and agricultural waste into feed ingredients is a key strategy to pursue this goal following the circular economy principle.

In Nigeria, the use of cassava roots as animal feed is a traditional backyard practice, but interest from the feed industry for this crop is relatively recent. In 1980, the first international workshop on cassava as livestock feed generated optimism about using cassava roots for replacing cereals, which had become increasingly scarce (Smith 1988). Feed mills in Nigeria were operating at 92% capacity in 1980, but this dropped to 26% in 1997 due to the shortage of local ingredients and the prohibitive cost of imported materials (Azogu et al. 2004), which coincided with an import ban on maize and soybean. Feed mills began searching for substitutes. Cassava chunks, chips and gelatinized grits were the first cassava products to draw attention from feed mills. However, the optimism gradually faded over time as research lagged and cassava was not used in animal feed, largely because yields were stagnant and cassava was growing in demand as food for the growing population.

Livestock can be fed on cassava peels. Farmers and agronomists have known this for years, but the idea had remained largely under-exploited. This situation changed in the 2000s as industry and researchers began to shift their interest from cassava roots to peels and as appropriate technology became available to process wet peels. This development was facilitated by a multi-stakeholder scaling partnership aided by the RTB scaling fund, using the Scaling Readiness approach (Sartas et al. 2020). As a result of this process, high-quality cassava peels (HQCP) have started getting into compound feed for poultry, fish, cattle, sheep and goats in 2018/2019 for some major feed millers, with satisfactory results. We will discuss this process in the following sections.

6.1.3 The Extent of the 'Peel Problem', Its Underlying Causes and Recent Developments

In Africa, processing cassava into food is primarily a manual and labour-intensive activity, typically performed by women, either individually at the household level or collectively in specialized processing groups (Hillocks 2002). More than 90% of cassava processing requires hand peeling. As a result, every year, Nigerians generate 15 million tons of peels, stumps (ends of roots) and undersized and damaged roots from processing cassava into various products (Fauquet 2014).

While cassava peels can be fed to livestock, they are poisonous if not properly processed. Peels have high levels of hydrogen cyanide (HCN), particularly in bitter cassava varieties, which are the most common in Nigeria. Sun drying is an effective way to reduce HCN levels significantly. However, improperly dried peels can be contaminated with mycotoxins, toxic compounds produced by fungi that can have serious health consequences for people who consume meat, milk or eggs.

Sun drying takes about 2–3 days in the dry season, but this is not viable in the rainy season when most cassava is harvested, leaving millions of tons of wet peels to rot. In the rainy season, lactic acid-laden, smelly effluent from rotting heaps contaminates nearby streams, wells and underground water (Fig. 6.1). In the dry season, heaps are often set on fire, and the acrid smoke pollutes the air (Fig. 6.2). Millions of tons of fermenting peels also emit greenhouse gases (Obianwa et al. 2016). During the dry season, about half of the processors in Nigeria try to dry up to 20% of their wet peels to sell or feed their own livestock. In rural Nigeria, peels are often given away to the workers who peel the cassava roots, so the peels can be dried and fed to their animals, especially goats (Azogu et al. 2004). However, these practices absorb only a fraction of the massive amount of peels generated in the country annually.

Manual peeling inevitably removes part of the cassava root's flesh along with the peels. It is estimated that approximately 22% of the fresh root weight (including the peels) is removed when roots are manually peeled. Enhancing hand peeling efficiency can reduce this to approximately 18% and save about 270,000 tons of cassava flesh annually, worth US$[1] 17.5 million, in southwest Nigeria alone (Bennett and Naziri 2013). However, procuring these savings would require the adoption of specially designed knives and considerably increase the time required for peeling.

In spite of recent advances in developing cassava peeling machines in Nigeria, it does not appear that the quantity of peels resulting from manual processing

[1] Exchange rate, USD 1 = NGN 480 at the parallel market where the bulk of foreign currency sourcing is happening

Fig. 6.1 A typical dumping site for cassava peels. (Photo: I. Okike (ILRI))

operations will decline in the foreseeable future. Egbeocha et al. (2016) conducted a review of cassava peeling machines and found their performance to be largely unsatisfactory for small-scale processors, who constitute the backbone of cassava processing in Africa. Kolawole et al. (2016) evaluated seven peeling machines and found that peeling efficiency was 0–96% while flesh loss was 7–96%. The latter compares very poorly with the 4% flesh loss for traditional manual peeling and 2–3% for peeling by women who have been specifically trained by the International Institute of Tropical Agriculture (IITA).

However, in spite of their current low efficiency, mechanical peeling is being increasingly adopted by some medium-to-large-scale processing enterprises that value the higher output capacity and the faster processing times. This is particularly true for industrial starch extraction, which usually requires the rapid processing of large amounts of fresh roots and does not need thorough removal of the external cortex that forms the peel with the periderm. For other cassava-based products, female peelers are still used to apply the finishing touches to clean the root of vestiges of peels after mechanical peeling. Therefore, mechanical peeling does not represent an immediate or foreseeable threat to the commercial exploitation of cassava peels nor to women's job opportunities. Unless the efficiency of mechanical peelers is dramatically increased, their wider adoption would simply generate more peels. These peels, in the meantime, could be processed into HQCP mashes (Fig. 6.3).

Fig. 6.2 Attempts to eliminate cassava peels by burning them. https://www.flickr.com/photos/ilri/43915310274. (Photo: I. Okike, ILRI)

6.2 What Is the Innovation Package?

The core innovation is a processing method for turning wet peels into HQCP mash to use as a feed ingredient. This method circumvents the challenge of drying, which is the most limiting constraint to using cassava peel as feed, reducing drying time from 2–3 days to just 6–8 hours in the dry season by grating, mechanical dewatering, fermenting, pulverizing, sieving and then sun-drying the peels (Fig. 6.4), as detailed by Okike et al. (2015). The steps essentially replicate the age-long processes involved in making cassava storable and safe for human consumption. In the wet season, sun drying is still possible but takes longer due to low intensity of the sun and intermittent periods when the mash spread for drying has to be covered and protected from rain. However, under these conditions, the long time required for reducing the moisture content to the ideal level facilitates fungal growth, which contaminates the product. As such, the sun-drying option is not recommended

Fig. 6.3 An example of peels and wasted roots from a peeling machine, amenable to further processing into HQCP mashes. (Photo: P. Kolawole, IITA)

Fig. 6.4 Steps to process fresh cassava peels into high-quality cassava peel products

Table 6.1 Attributes of the four distinct HQCP products

Product type	Attributes	Suitable species to feed
HQCP cake	High moisture (38–42%), low keeping quality (about 7 days). Total energy 2,947 kcal/kgDM and 9.8% fibre	Cattle, goats, sheep and pigs
HQCP whole mash	10–12% moisture and good keeping quality (more than 6 months in storage). Total energy 2,947 kcal/kgDM and 9.8% fibre – Same as for cake	Cattle, goats, sheep and pigs
HQCP fine mash	*Premium product*. 10–12% moisture and good keeping quality (more than 6 months in storage). Total energy 3,039 kcal/kgDM and 8.2% fibre	Poultry, fish and young pigs
HQCP coarse mash	10–12% moisture and good keeping quality (more than 6 months in storage). Total energy 3,039 kcal/kgDM and 15.6% fibre	Cattle, sheep, goats and adult pigs

during the wet season. During wet seasons, additional options for drying include toasting and flash drying.

Regardless of the drying method, four distinct products with different attributes and potential applications result from the process (Table 6.1).

1. *Cassava peel cake* has high moisture content, has a short shelf life of about 1 week and can be fed to cattle, sheep and goats. Due to its high perishability, it is designed to be marketed near processing centres.
2. *HQCP dried whole mash* is drier (moisture content below 12%) and can be stored for up to 6 months and transported over longer distances. It can be a feed ingredient for cattle, sheep, goats and also pigs, which have better capacity to digest fibre than poultry and fish.
3. *HQCP coarse mash* is fibrous and low in energy with a shelf life of 6 months. It can be used for feeding cattle, sheep, goats and adult pigs.
4. *HQCP fine mash* is the premium product, low in fibre, high in energy with a shelf life of 6 months and suitable for poultry, fish and piglets. The HQCP whole mash is mechanically sieved to separate it into HQCP coarse and HQCP fine mashes (Fig. 6.5).

All of these innovative processes reduce the cyanide content to approximately 35 ppm, well below safe levels (90 ppm) for livestock feed (Samireddipalle et al. 2016).

Additional elements of the innovation package include recommendations for feed use, especially:

- FeedCalculator® for formulating least cost balanced rations incorporating HQCP
- Protocols, business development guidelines and plans to guide investments at diverse scales for processing and marketing HQCP mashes (e.g. small scale, two graters with toasters; medium scale, four graters with 4-tonne flash drier related)
- Loan application guidelines for engaging with credit and financial institutions
- District and state-level maps georeferencing cassava processing clusters on Cassava Peel Tracker®, which incorporates information on quantity of peels

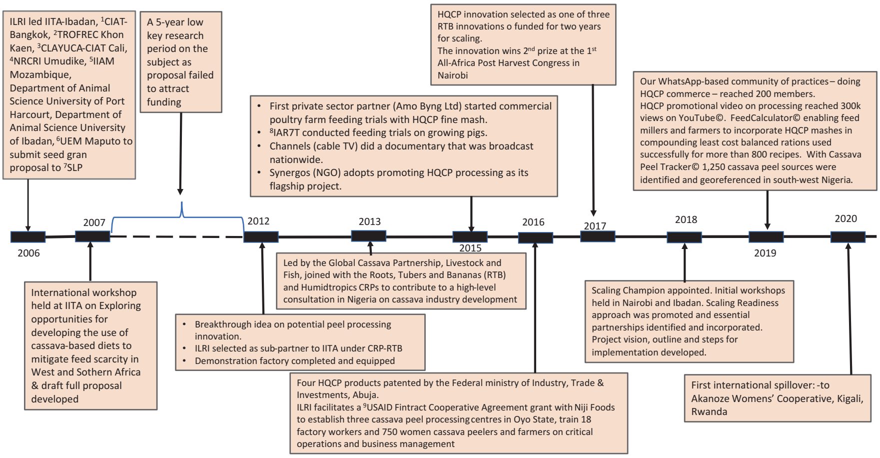
Fig. 6.5 A mechanical sieve – coarse mash retained in the wooden box and fine mash captured in the basin after separation https://www.flickr.com/photos/ilri/23003496544/. (Photo: I. Okike (ILRI))

generated daily by the processing clusters by season and contact details of key persons
- Capacity development for processors on best practices in production, equipment maintenance, personnel safety, product and factory hygiene and cassava peel business registration on Cassava Peel Tracker®
- Bookkeeping

Finally, the innovation package includes a WhatsApp™-based community of practice (CoP) platform known as Cassava Peel First Movers for exchanging knowledge and information and promoting HQCP products. Efforts are also ongoing to have HQCP products recognized by the Standards Organisation of Nigeria (SON) and their standard physical and nutritional qualities listed in the SON manuals.

6.2.1 History of CGIAR Research to Develop the Use of Peels as Feed

In the early 2000s, a flurry of government-backed activities brought together researchers and the public and private sectors to herald a cassava revolution in Nigeria with options for developing a livestock feed industry based on cassava and its derivatives. At that time, the focus was still on the use of cassava roots as feed ingredient. In 2007, the International Livestock Research Institute (ILRI) received a



[1]International Center for Tropical Agriculture, [2]Tropical Feed Resources Research and Development Center, Khon Kaen University, Thailand. [3] Latin American and Caribbean Consortium to Support Cassava Research and Development, Cali, Colombia, [4]National Root Crop Research Institute, Umudike, Nigeria, [5]Instituto de Investigacao de Mocambique, Mocambique. [6]Eduardo Mondlane University, Maputo, Mocambique. [7]Systemwide Livestock Project of the Consultative Group on International Agricultural Research (CIGAR).[8]Institute for Agricultural Research and Training Ibadan, Nigeria.[9]United States Agency for International Development.

Fig. 6.6 Timeline of CGIAR research to develop the use of cassava peels as feed

seed grant through the CGIAR Systemwide Livestock Programme (SLP) to conduct initial research on cassava peel as livestock feed. A partnership was later established that included IITA and various research institutes from Nigeria, Mozambique, Colombia and Thailand. The initiative marked the beginning of CGIAR research on the use of cassava peels as animal feed. However, it would not be until the early 2010s that the CGIAR would begin exploring the technical viability of processing cassava peel into HQCP products (Fig. 6.6).

6.2.2 *Proof of Concept and Feeding Trials Under the Auspices of RTB*

After the partnership failed to attract the expected funding, there was a lull in research until 2012, when ILRI engaged in an IITA-led initiative under the CGIAR Research Program on Roots, Tubers and Bananas (RTB). The new initiative aimed at addressing the following research questions:

1. Are HQCP products acceptable to livestock?
2. Are HQCP products economically viable?
3. Are HQCP products have potential for wide adoption and going to scale?

With RTB funding support, a demonstration pilot factory was built, and a multi-disciplinary, multi-institutional team of scientists with expertise in animal science, engineering, food science and pathology came together to investigate options for hygienic and safe processing of wet peels. To complement the RTB effort, the Feed and Forages team of the CGIAR Research Program on Livestock and Fish initiated

Table 6.2 Nutrient profiles and prices of HQCP products compared to maize in March 2021 (dry season)

	HQCP (whole)	HQCP (fine)	HQCP (coarse)	Maize
Starch (%)	66.7	69.0	55.0	68.8
Protein (%)	2.5	2.6	2.8	8.8
Fat (%)	1.4	1.2	1.2	4.1
Crude fibre (%)	9.8	8.2	15.6	2.6
Crude ash (%)	5.8	6.6	3.5	1.4
Total energy (kcal/kgDM)	2947	3039	2495	3840
Price/tonne (naira)	67,000[a]	75,000	50,000	200,000
Price/tonne (US$)	139.56	156.25	104.17	416.67

Source: For HQCP products: www.masterlab.nl. For the HQCP Scaling Project and for maize: https://feedtables.com/content/maize-flour-crude-fibre-2-10

[a]HQCP products are mainly marketed as fine and coarse mashes although produced as HQCP (whole) before separation. HQCP (whole) yields two parts fine for one part coarse, so its price per tonne can be derived as ((2 × 75,000) + (1 × 50,000))/3 = NGN 67,000 per tonne

a new research activity to explore related small-scale business development services and technology to capitalize on cassava peel waste by-products to increase animal feed availability within selected livestock and fish value chains.

After producing a few tons of HQCP whole, fine and coarse mashes of consistent nutrient profiles and physical qualities (e.g. texture, particle size, moisture level), laboratory analyses confirmed the products were safe with acceptably low levels of cyanide and aflatoxins. The whole HQCP mash was found to have more than two-thirds the metabolic energy (ME) of maize (2,947 vs. 3,840 kcal/kg of dry matter), and these levels were even higher for HQCP fine mash (Table 6.2).

Feeding trials were then established at the ILRI research station with ruminants, poultry and pigs for assessing the palatability of HQCP. Following satisfactory results of the palatability trials and in an effort to create awareness of the products, samples of HQCP coarse mash were taken to ruminant markets across Oyo State, where cattle, sheep and goats consumed it readily.

Most of those involved were from the CGIAR until 2015, when research began to provide solid evidence about the safety and hygiene of HQCP products for animal feed. CGIAR researchers continued research on product development and assessing the technology, but to prove the concept and move towards scaling, partnerships were expanded to include key private-sector players that had toured IITA labs and feeding trials, including ILRI experiments, and expressed interest in setting up their own trials. These groups included Durante Fish Industries, Amo Byng Ltd., Nine Stars Fish Farms and Hatchery Ltd., and Niji Foods. Furthermore, the NGO Synergos and the Federal Ministry of Agriculture and Rural Development (FMARD) were also involved.

On-farm and on-station animal feeding trials were conducted in 2016 at the following three locations.

Table 6.3 Results of feeding trials at Amo Byng

	Groups				
HQCP fed (kg/tonne)	Maize based	50	75	100	125
Chicks housed	100	100	100	100	100
Mean age (days)	35	35	35	35	35
Birds harvested	97	98	97	99	97
Mortality (%)	3	2	3	1	3
Feed consumed (kg)	3.092	3.355	3.047	2.815	2.9
Live body weight (kg)	2.23	2.208	2.184	2.135	2.054
Feed conversion ratio (FCR)	1.387	1.519	1.395	1.319	1.412
Total feed consumed/bird (naira)	265	290	266	247	258
Feed cost/kg liveweight (naira)	118.8	131	121.7	115.6	125.6
Sale value/bird (naira)	892	883	874	854	822
Gross margin/bird (naira)	627	593	608	607	564

Source: Amo Byng Ltd., Awe, Oyo State, Nigeria

1. *Amo Farm Sieberer Hatchery Ltd*, a subsidiary of Amo Byng Ltd., Awe, Oyo State, trialled HQCP coarse mash with feedlot cattle and found it could substitute up to 10% of feed resources. They also conducted four on-farm feeding trials with commercial poultry (three with broilers and one with layers) using HQCP fine fraction. They tested different inclusion rates of mash in the total diet (Table 6.3) and found that the 10% inclusion rate (100 kg of HQCP fine mash in 1 tonne of feed) resulted in the best growth rate, lowest feed intake and lowest mortality. The response in broilers was better than the response in layers. These results convinced the company to start incorporating processed cassava peels into poultry and cattle diets, though supply was a major constraint. Furthermore, HQCP fine mash fortified with full fat soy, DL-methionine and soy oil could replace up to 25% of the maize in broiler diets. In spite of fortified HQCP being significantly cheaper than maize, the biofortification option was not further pursued by the project.
2. *Institute of Agricultural Research and Training (IAR&T) of the Obafemi Awolowo University, Moor Plantation, Ibadan, Oyo State*, conducted on-station trials with weaned and growing pigs. They found that HQCP fine mash could replace 75% of maize in the diet of growing pigs, reducing feed costs by 4% with no adverse effect on the growth performance (Adesehinwa et al. 2016).
3. *ILRI farm at IITA, Ibadan, Oyo State*, hosted on-station trials which showed that cassava peels and leaves, fed in the ratio of 70:30 on a dry matter basis, could be the sole feed for cattle, sheep and goats and would reduce feeding costs.

6.2.3 *Supporting Private Sector Partners to Take Up the Innovation*

In September 2016, ILRI helped Niji Foods acquire a grant under Fintrac's Cooperative Agreement with the US Agency for International Development (USAID). Under this initiative, Niji Foods, with support from ILRI, was to establish three HQCP processing centres in Oyo State, train 18 factory employees, six administrative staff and 750 women cassava peelers and farmers on critical operations and business management. Amo Byng Ltd. committed to buying the HQCP products from Niji Foods, but, ultimately, the purchase agreement with Amo Byng Ltd. did not materialize as Niji Foods was offered better prices from other buyers.

6.2.4 *Registration of Products as First Step Towards Developing Product Standards*

While conducting feeding trials and broadening the partnership, the HQCP project staff approached the Commercial Law Department, Trade Marks, Patent and Designs Registry of the Federal Ministry of Industry, Trade and Investments in Abuja, who granted an umbrella patent to ILRI that covered four HQCP products under trademarks as follows:

1. Cassa peel mash®, previously referred to as HQCP fine mash
2. Cassa peel bran®, previously referred to as HQCP coarse mash
3. Cassa peel cake®, previously referred to as HQCP cake
4. Cassanules®, granulated HQCP that was designed to replace sorghum for the production of Aflasafe®

6.3 Value and Impacts of Innovation

6.3.1 *Societal Value of Innovation (Potential Economic and Environmental Value)*

The raw material for HQCP production is freely available as approximately 98% of peels in Nigeria are dumped. As previously mentioned, the drying techniques vary according to the season and scale of operations. With sun drying as the dominant mode of processing, the energy requirement is insignificant. Depending on the drying method (sunshine, toasting or flash drying), production costs of HQCP whole mash vary from US$96 to US$107 per tonne (Table 6.4), while the feed industry

Table 6.4 Production budget for HQCP whole mash in the wet and dry seasons (US$/tonne) and market price projections assuming 25% markup during 2015

		A	B	C
Item id.	Item	Budget for fresh peels and initial processing	Budget for a tonne of wet cake = A * 2	Budget for a tonne of whole mash = B * 1.5
a	Fresh peels (dry season)	10.00	20.00	30.00
b	Fresh peels (wet season)	7.00	14.00	21.00
c	Transportation (US$/ tonne/25 km)	1.50	3.00	4.50
d	Loading labour (0.5 h)	0.35	0.70	1.05
e	Off-loading labour (0.5 h)	0.25	0.50	0.75
f	Grating	8.80	17.60	26.40
g	Packing into bags, loading and dewatering by hydraulic press	2.50	5.00	7.50
h	Woven plastic bags (100 reusable bags x 10 kg)	0.50	1.00	1.50
i	**Production of HQCP wet cake and HQCP whole mash (dry season) =** (a + c + d + e + f + g + h) of column B		**47.80**	**71.70**
j	**Production of HQCP wet cake and HQCP whole mash (wet season) =** (b + c + d + e + f + g + h) of column B		**41.80**	**62.70**
k	**Market price of cake assuming 25% markup (dry season)** = i * 1.25		**59.75**	**74.69**
l	**Market price of cake assuming 25% markup (wet season)** = j * 1.25		**52.25**	**65.31**
m	Pulverizing and sieving cake			2.40
n	Labour for spreading and stirring wet mash			6.00
o	Labour for toasting wet mash			10.80
p	Fuel (coal) for toasting			16.80
q	Packing finished products into bags and sealing			4.00
r	Woven plastic bags (40 new bags × 25 kg)			10.00
s	**Production of solar dried mash (dry season)** = (i + m + n + q + r)			**96.10**
t	**Production of toasted mash (wet season)** = (j + m + o + p + q + r)			**106.70**
u	**Market price for solar dried mash assuming 25% markup (dry season)** = s * 1.25			**120.13**
v	**Market price for toasted mash assuming 25% markup (wet season)** = t * 1.25			**133.38**

Source: Analysis based on data from research notes of the cassava peel project

buys HQCP coarse and fine mashes at US$ 100–150 per tonne, respectively, which is less than half the price of maize (Table 6.2). The feed industry is willing to pay for HQCP mashes because of their nutritional content and the satisfactory feedback received from the customers.

Production budgets for both dry and wet seasons indicate that products can reach the market with a markup of 25% on total cost of production and still remain below half the price of maize (weight for weight), which has largely remained the feed industry's benchmark price for HQCP (Table 6.4). Total production cost using sun drying in the dry season is US$97, while the cost of production in the wet season, based on toasting, was US$107 per tonne. A projected market price per tonne of HQCP whole mash of US$120 in the dry season and US$133 in the rainy season would result in a profit margin of 25%, which should keep a business running. However, current market prices (as of Feb 2021) are even higher, approximately US$150 per tonne. It is important to note that while the cost of toasting increases production cost in the rainy season, the price offered for HQCP fine mash is higher during that time because usually, maize prices are highest during the rainy season prior to harvest. Therefore, the additional cost incurred for drying does not necessarily affect profitability adversely.

Cash flow analysis calculated over 5 years of operation for an enterprise producing 2.5 tons of peel cake per day showed that an investment cost of US$9,200 and a working capital of US$100/day would yield a gross revenue of approximately US$39,500 per year, break even in year 4 and result in a net present value (NPV) of US$6,026 (Table 6.5). Other sizes of operations were also analysed with similar results, suggesting a bankable investment (spreadsheets are available on request).

In terms of achievable markets, it is worth noticing that HQCP fine mash is the star product of the core innovation. Because of its lower fibre content and despite

Table 6.5 Five-year budget for an operation processing 2.5 tons of wet cassava peels per day in USD

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Revenue items (USD)						
High-quality cassava peel (wet) cake		37,500	39,375	41,344	43,411	45,581
Gross revenue		37,500	39,375	41,344	43,411	45,581
Cost items (USD)						
Investment (grater, hydraulic press units, well, shed)	9200					
Fresh cassava peels		15,000	15,750	16,538	17,364	18,233
Collation and transportation		1575	1575	1575	1575	1575
Labour and cost of grating		13,200	13,200	13,200	13,200	13,200
Cost of dewatering		5250	5250	5250	5250	5250
Maintenance		200	200	200	200	200
Earnings before taxation		2275	3400	4581	5822	7124
Taxation (1%)		22.75	34	46	58	71
Profit and loss	−9200	2252.25	3366	4535	5763	7053
Present value factor	100%	85%	72%	61%	52%	44%
Present value	−9200	1909	2417	2760	2973	3083
Cumulative present value	−9200	−7291	−4874	−2113	859	3942

Source: Analysis based on data from research notes of the cassava peel project
Internal rate of return = *32%*; working capital, US$35,025 in year 1, going up to US$38,258 in year 5

being roughly 50% more expensive than HQCP coarse mash (Table 6.2), the fine mash is preferred by feed millers for inclusion in feed for monogastrics, especially poultry and fish (incidentally, these are the two most industrialized sub-sectors of the animal production industry in Nigeria and capable of absorbing the highest volume of HQCP fine mash). The potential for HQCP inclusion in the poultry sector is particularly remarkable. Nigeria produced 11.5 million tons of maize and imported 0.5 million tons in 2020. About 60%, or 7.2 million, of these 12 million tons went into poultry feed (Agweek 2021). At a 10% inclusion rate (as suggested by the trials hosted by Amo Farm Sieberer Hatchery), the poultry feed industry alone could replace approximately 720,000 tons of maize per year with same amount of HQCP fine mash. Similarly, if 10% of the approximately 900,000 tons of maize currently used in fish feed manufacturing (CORAF 2020) was replaced by HQCP fine mash, this would create an additional market opportunity of approximately 90,000 tons per year. Therefore, the poultry and fish sectors alone have the capacity to absorb up to 810,000 tons of HQCP fine mash. At a selling price of US$100–150/tonne, this would open up an $80–120 million industry annually that could employ an estimated 20,000 people, 80% of whom would be women.

6.3.2 Who Does This Innovation Package Impact?

Business Opportunities

Wide adoption of HQCP can create a new, commercially viable business and generate income opportunities. Cassava producers, workers, entrepreneurs, livestock farmers and consumers of livestock products can benefit from exploiting this upgrade to the value chain:

1. Approximately four million cassava producers would have the opportunity to sell cassava peels, earning new income that could also spur investment in cassava productivity.
2. *Gari* processors, who generate most of the peels (in some 9000 processing centres nationwide) would enjoy new revenue from selling the waste peels while cleaning up their workplaces (usually nearby their homes), thus improving the health and well-being of workers.
3. Feed millers would have access to cheaper raw materials than maize, even when HQCP is fortified with soy products.
4. Incorporating HQCP into feed mills will reduce feed production costs and release maize for human consumption.
5. Livestock and fish producers would have access to cheaper feed of a similar quality to current products, lowering their operating costs.
6. Consumers would benefit from cheaper meat, milk and eggs, contributing to diets richer in protein and essential micronutrients.
7. Due to increased feed availability, cattle could be produced more intensively with less movement, reducing conflicts between pastoralist and farmers.

8. Dairy production would increase, reducing imports of milk.
9. New job opportunities would be created for people collecting, processing and selling HQCP products. See also a YouTube video[2] on ‘Transforming cassava peels into animal feed’.

Benefits for Women: An Example from Synergos Project

One of the cassava peel project’s partners, Synergos, promoted HQCP to women’s groups and cooperatives through the State Partnership for Agriculture Programme (SPA), funded by the Bill & Melinda Gates Foundation (2016–2019). The SPA project sought to support women and nutrition in the shift of agriculture from subsistence to commercial production with the goal of increasing incomes and improving livelihoods. Hence, the project provided a good opportunity to Synergos to create a revenue stream for cassava processors, especially women, by establishing prototype HQCP learning centres where cassava peels were collected, processed into HQCP mashes and sold to herders and feed millers.

The SPA used the prototype learning centres to improve relations with farmer cooperatives in Benue and Kogi. In 2016, Synergos funded the training of two women and two men from each of these states as master trainers at ILRI, Ibadan. Ten satellite clusters were equipped with grating machines to process cassava peels and supply HQCP mashes. Over the years, about 2000 women have benefitted directly or indirectly from this innovation in Benue State.

In Kogi State, 20 women and ten female youths were involved in clusters of cooperatives. Synergos, in collaboration with IITA and ILRI, repaired and converted an existing processing centre in Ojapata into a prototype learning centre and helped procure processing equipment. Here, one of the women, Mrs. Jummai Mohammed, aggregates cassava peels from other processing centres in Ojapata and supplies them to the HQCP centre for making fine mash. She sells the fresh cassava peels at 0.52–0.79 per 100 kg bag, and the new income has allowed her to send her children back to school. With scaling fund support from ILRI and the Technology for African Agricultural Transformation (TAAT) initiative, Synergos set up an additional HQCP processing centre for an all-female cooperative group in Ejule. This work was made possible through a partnership in which the women’s group provided land, shelter and security for the centre.

In Ogun State, Valueman International also engaged 32 women in an HQCP processing factory, while IFAD and Synergos trained 50 processors, including 30 women. Currently, over 500 women in Nigeria work in the HQCP value chain, and more are projected to benefit as demand increases nationally for HQCP in animal and fish feed production.

The Synergos project has been successful in promoting the HQCP innovation among women (individually and in groups) and impacted positively on the livelihood of beneficiaries. This benefit can be attributed to the coordinated effort of a

[2] The video (http://bit.ly/2j7bRu3) has been viewed more than 336,000 times, sparking 2,000 likes and several questions from young school leavers about where to get training and equipment. Clearly, there is interest from young people to engage in such an enterprise.

wide range of partners, including the Ministry of Agriculture and other national agencies (e.g. Business Innovation Facility), research organizations (ILRI and Kogi State University) and private sector actors (Everest Feed and farmers cooperatives).

Though largely successful, there are still some challenges to be addressed and overcome:

1. Access to processing equipment and maintenance. Skills needed to make the equipment are still very low.
2. Transportation to market. It is expensive for HQCP processors to deliver processed HQCP to final markets.
3. Access to credit. Financial institutions are reluctant to loan funds to HQCP processors to invest in equipment.

6.4 The Approach to Scaling the HQCP Innovation

6.4.1 The Influences of the Scaling Readiness Approach

Initially, there was little emphasis on scaling for HQCP. This changed when the lead innovator was named a ‘scaling champion’ and HQCP transformation was selected as one of the first of three innovations to be supported through the RTB Scaling Fund Project for 2018–2019. The Scaling Readiness approach (Sartas et al. 2020) makes clear that innovations scale as packages, and packages include core and complementary innovations, which, for HQCP, were unpacked into ‘hard’ (technical) and ‘soft’ (culture and socioeconomic) components (Fig. 6.7).

Such unpacking of components helps identify what needs to be addressed to help a core innovation go to scale. This work will inform strategic considerations regarding priorities and the roles needed from potential partners by disciplinary advantage. The scaling project team used the concept of ‘Scaling Readiness’ to assess the innovation packages. ‘Innovation readiness’ refers to the demonstrated capacity of an innovation to fulfil its contribution to development outcomes in specific locations. This is presented in nine stages showing progress from an untested idea to a fully mature proven innovation. ‘Innovation use’ indicates the level of use of the innovation or innovation package by the project members, partners and society. This shows progressively broader levels of use beginning with the intervention team who develop the innovation to its widespread use by users who are completely unconnected with the team or their partners. ‘Scaling Readiness’ of an innovation is a function of innovation readiness and innovation use. Table 6.6 provides summary definitions for each level of readiness and use adapted from Sartas et al. (2020).

Examining components through the Scaling Readiness approach allows researchers and implementers to critically examine the constrained ones while broadening partnership scoping and reflection.

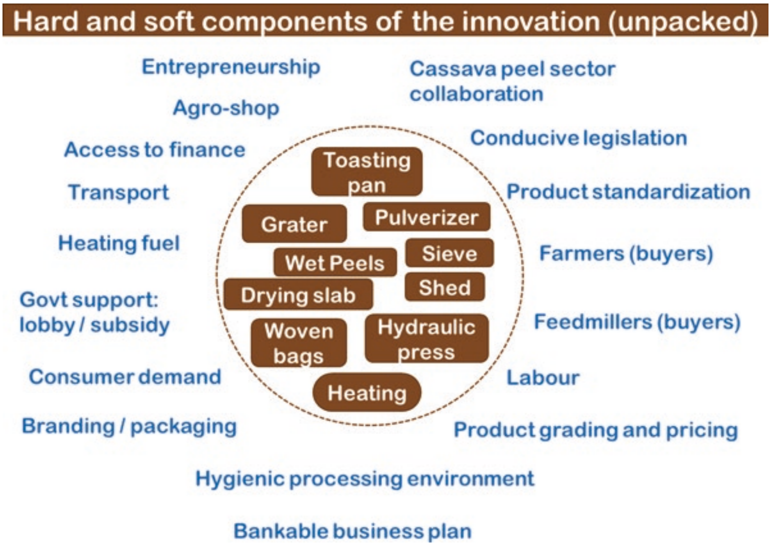


Fig. 6.7 Unpacking the innovation package to reveal its 'hard' and 'soft' components (brown and blue colours, respectively)

Table 6.6 Summary definition of levels of innovation readiness and use (Sartas et al. 2020)

Stage	Innovation readiness	Innovation use
1	Idea	Intervention team
2	Basic model (testing)	Direct partners (rare)
3	Basic model (proven)	Direct partners (common)
4	Application model (testing)	Secondary partners (rare)
5	Application model (proven)	Secondary partners (common)
6	Application (testing)	Unconnected developers (rare)
7	Application (proven)	Unconnected developers (common)
8	Innovation (testing)	Unconnected users (rare)
9	Innovation (proven)	Unconnected users (common)

For HQCP innovation, unpacking and Scaling Readiness analyses revealed that constraints to scaling existed more within the 'soft' components (e.g. environment and product hygiene, processor/user interfacing, grading and pricing, electricity and labour) rather than around the 'hard' components (e.g. grater, hydraulic press and mechanical sieve). If the 'soft' components are the cultural and social economy of the technology, then more partners with competence in these areas are required on board.

In the diagnosis to assess the innovation package in terms of its innovation readiness and innovation use, its individual components were scored on a scale of 1–9 for component readiness and component use. Owing to the large number of components for the innovation package, the diagnosis was partitioned into hard and soft components (Figs. 6.8 and 6.9).

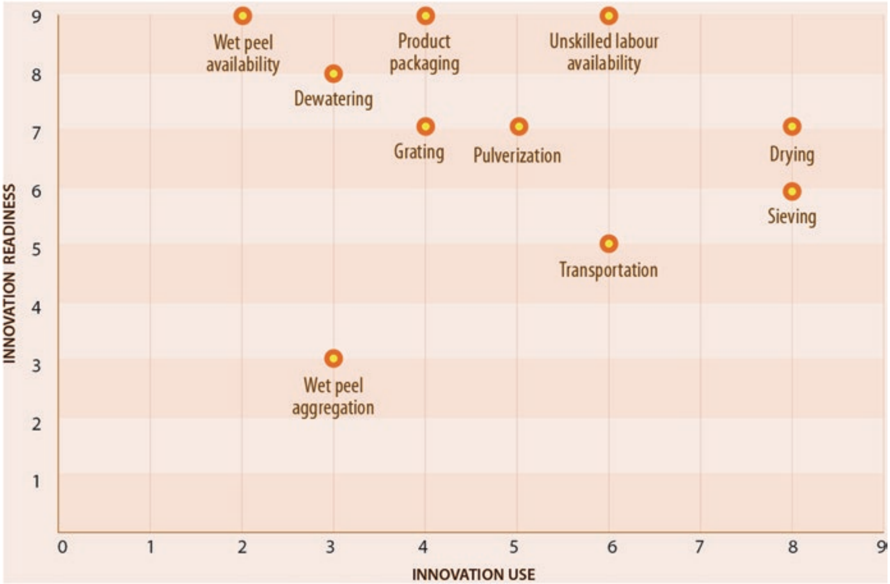


Fig. 6.8 Hard components of the HQCP innovation package. (Source: RTB Scaling Fund Project 2018–2019)

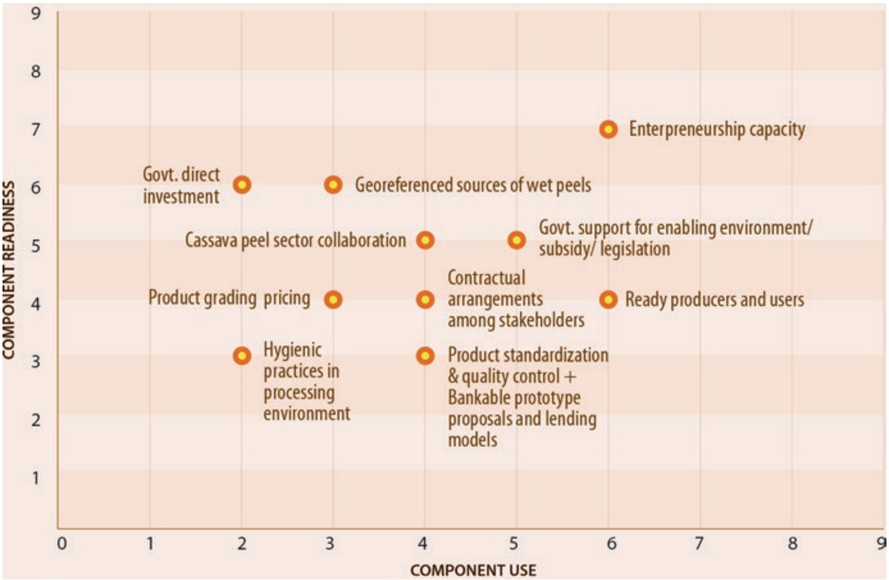


Fig. 6.9 'Soft' components of the HQCP innovation package. (Source: RTB Scaling Fund Project 2018–2019)

From the diagnosis of the hard components, aggregation of wet peels showed the lowest innovation readiness and use, thus constituting an important bottleneck for scaling the HQCP innovation. This triggered the process of developing the scaling strategy considering options to address the identified bottleneck innovations according to Sartas et al. (2020). The initial consideration was to outsource the aggregation of wet peels to a refuse disposal company that would collect and deliver the peels to the processing factories. However, the major problem was the highly dispersed nature of cassava processing centres from which peels have to be collected. Eventually, a web-based platform, called Cassava Peel Tracker®,[3] was developed, and 1,250 locations were surveyed, geo-referenced and mapped in four states in southwest Nigeria to address the bottleneck. The platform provides information on quantity of wet peels generated per location per day (average of 3.3 tons) and the contact details of leaders of the centres. As it turned out, the quantity of peels produced around small enterprises is often sufficient for their operation; however, large enterprises, for whom fresh peels aggregation would be a bottleneck, are yet to emerge.

The diagnosis of the soft components showed that hygiene in the processing environment was at the lowest rung of readiness (Fig. 6.9). The project attempted to tackle this issue at two levels:

(i) At the federal level in the Ministry of Environment, which budgeted to establish six HQCP processing centres in strategic locations to promote hygienic practices. The required funds, however, failed to materialize.
(ii) At the level of individual entrepreneurs through training.

All the options for addressing constraints suggested by the Scaling Readiness approach failed, and as a result, few of the entrepreneurs were able to follow the prescribed hygienic practices (e.g. building underground drainage for effluent). Product standardization and quality control, bankable prototype proposals and lending models were at a similarly low rung of readiness and have remained major constraints to date.

6.4.2 Role of Scaling Workshops in Strengthening Partnerships

The RTB scaling project workshops reiterated the need to focus on the soft components of the HQCP innovation package. This led to the identification of activities needed to address the main bottlenecks for taking the innovation at scale: facilitate access to credit and develop bankable business proposals; establish a cassava peel sub-sector collaboration or community of practice; and ensure product standardization, marketing, promotion, supportive legislation, awareness creation and advocacy.

[3] https://seedtracker.org/peeltracker/

Based on this, the Bank of Industry (BoI) was engaged to facilitate access to credit, and the National Office for Technology Acquisition and Promotion (NOTAP) began to help with promotion. Single Spark (makers of FeedCalculator® for feed formulation) and the Raw Materials Research and Development Council (RMRDC) began to support the strengthening of the hard components of the technology. Cassava Peel First Movers groups were established as the community of practice. At this point, the scaling consultant helped the project staff develop a way to track partnerships (Table 6.7).

6.5 Development Outcomes from Making and Using HQCP

This section presents the RTB scaling project's achievements and challenges, which were documented through a short, cross-sectional survey conducted shortly after the end of the intervention. The section is structured around the project's development outcomes.

6.5.1 Development Outcome 1

Two major feed millers in Nigeria are regularly incorporating HQCP mash in their commercial rations.

Among major feed millers, Premium Fish Feeds and Premier Feeds incorporate HQCP fine mash directly into their rations, while Nine Stars uses powdered HQCP (indirectly) as a binder in their fish feed. Premium Fish Feeds, which is one of the top five largest feed mills in Nigeria, uses 7–10 tons of HQCP weekly. Premier Feeds began using 100 tons per week and have now expanded to 200 tons a week. Premier Feeds was initially procuring HQCP from their sister factory, Thai Farms, which eventually could not satisfy their expanding demand. Presently, the additional quantity is purchased from one of the project's trainees, Kofo Agro, at a price of US$ 160 per tonne.

6.5.2 Development Outcome 2

Two hundred female and male processors are organized and up to 60% of them linked to markets and selling HQCP mash to commercial feed millers under contractual arrangements.

Small- and medium-scale enterprises that emerged during scaling activities are taking root around HQCP mash production and sale to feed millers.

The post-intervention survey was conducted on three groups of entrepreneurs: (i) 36 of the more than 200 small-scale entrepreneurs belonging to the Cassava Peel

Table 6.7 List of partners and tracking partners

What characterizes partner in relation to scaling project							
Prospective partners	Importance for scaling project	Aware of the innovation proposed and its scaling prospects	Supportive and capable of contributing to scaling	Actively participating in helping innovation go to scale	Actively propagating the innovation without support by scaling	Level of effort to help innovation go to scale	Strategy for how to involve them
	Score 1–5	Tick which one applies				Score 1–5	Description
Amo Byng	4	✓	✓	✓		4	Classification, contractual arrangements for commerce, updates through collaborative fora, participation in meetings
Top feeds	4	✓	✓			1	Classification, contractual arrangements for commerce, updates through collaborative fora, participation in meetings
Durante	3	✓	✓	✓			Updates through collaborative fora, participation in meetings
Nine stars	3	✓	✓	✓	✓	4	Updates through collaborative fora, participation in meetings
Niji foods	3	✓	✓			3	Participation in meetings
Synergos	3	✓	✓	✓	✓	4	Factories and with clientele, updates through collaborative fora, participation in meetings

(continued)

Table 6.7 (continued)

What characterizes partner in relation to scaling project							
Prospective partners	Importance for scaling project	Aware of the innovation proposed and its scaling prospects	Supportive and capable of contributing to scaling	Actively participating in helping innovation go to scale	Actively propagating the innovation without support by scaling	Level of effort to help innovation go to scale	Strategy for how to involve them
NOTAP	4	✓	✓			4	Through collaborative fora, participation in meetings
RMRDC	4	✓	✓			3	Through collaborative fora, participation in meetings
FMARD	4	✓	✓			2	Factories with selected cooperative groups, updates through collaborative fora
BoI	5	✓	✓	✓	✓	3	Beneficiaries for credit support, updates through collaborative fora, participation in meetings
Single spark	3	✓	✓			3	Promotion of FeedCalculator, updates
ILRI	3	✓	✓	✓		2	Project, updates through collaborative fora, participation in meetings
CIAT	3	✓	✓	✓		2	Project, updates through collaborative fora, participation in meetings
Indicative summary	3.5	100%	100%	54%	23%	2.8	

Source*:* RTB Scaling Fund Project 2018–2019

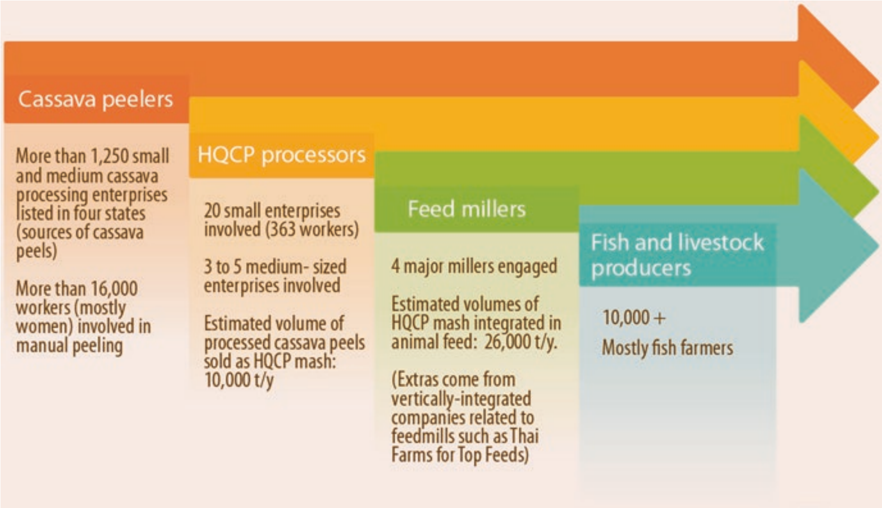


Fig. 6.10 A summary of stakeholders in the HQCP value chain in Nigeria. (Source: End of RTB Scaling Fund project survey, 2020)

First Movers CoP platform, (ii) all three medium-scale entrepreneurs involved with the project and (iii) all four feed millers with whom contractual arrangements were sought. There are 1250 small-scale cassava processors in four states, including more than 200 who belong to the CoP. There are as many as 20 medium-scale entrepreneurs, including those who were not involved with the project (Fig. 6.10).

Small-Scale HQCP Mash Producers

Almost all the 36 small-scale entrepreneurs surveyed had been among the over 200 people trained as a joint RTB-LIVESTOCK CRP activity in the demonstration factory at IITA campus in 2018 and 2019 on best practices in production, equipment maintenance, personnel safety, feed safety, hygiene, cassava peel business registration, bookkeeping, credit application and feed formulation of least-cost balanced rations incorporating HQCP. On a scale of 1 to 5, the training was rated 4.78 for content by respondents. Respondents said the most innovative and useful topics they learned about included how the process mimicked *gari* production, hygiene and feed safety, the use of FeedCalculator® and cash flow analysis.

The respondents already use wet peels as a feed ingredient for their own animals, but now they have identified aggregators for product marketing, good management practices and the promotion of HQCP in feed formulation to reduce costs. For reasons unknown at the time of writing, but probably related to the ease of getting cassava peel, the Cassava Peel Tracker was not popular among small-scale producers and was not used to identify clients or suppliers and/or to buy or sell cassava peels or cassava peel products. Some respondents suggested creating a wider base of processors and buyers to make the website visit worthwhile, while others suggested raising awareness about the existence of the tracker.

Those respondents who went on to adopt the technology and develop enterprises around it (approximately 10% of trainees) were mostly persons already engaged in one or more cassava-related activities – farmers, processors and feed producers. This result is not surprising as the training had a broad waste-to-wealth (w2W) theme around cassava peel that appealed to people already in the cassava business and for whom the required raw material was available free of charge or nearly so. The familiarity of HQCP processing equipment given its similarity to traditional *gari* processing equipment also meant that start-ups or switching from *gari* to HQCP processing was easy for such persons. It is also noteworthy that some 12% of the 36 small-scale producers surveyed started off after watching the demonstration video and/or watching others produce.

As expected, most of the 36 surveyed producers have made fresh investments in equipment and factory construction, while a few switched their previous investment in gari processing to HQCP processing, sensing that it would be more profitable. Investments ranged from US$ 150 to US$ 27,400. More than half of current producers have considered borrowing money to support their businesses, and of these, half of the credit demand is still in preparation. Preferences for credit sources were more for informal and family sources than banks.

A novel industry is developing around the cassava value chain and creating employment in its wake. At the time of the survey, 20 of the 36 respondents were producing HQCP mashes, with enterprises spread across south-east, south-south, southwest and north-central geo-political zones of Nigeria, employing a total of 363 persons (mean 10.8) with weekly production and sales of up to 10 tons of wet peel cake, 14 tons of whole HQCP mash, up to 15 tons of coarse HQCP mash and up to 16 tons of fine HQCP mash (Fig. 6.11).

Medium-Scale HQCP Producers

The three medium-scale HQCP producers who participated in the survey have produced fine mash, coarse mash and cassava peel cake since 2017/2018 for a wide range of clients, including feed millers and fish producers. The medium-scale producers have capacity to process up to 60 tons per week of wet peels and up to 120 tons per week of dried peels. In the past few years, clients have increasingly purchased HQCP products to overcome the problems of traditionally processed cassava peels (dusty and potentially contaminated with HCN and aflatoxins). The customers of the three medium-scale producers rate HQCP as ‘most important’ on product quality, while availability was the lowest concern. The issue of quality was predicated on nutrient profile (high energy content) and low moisture linked with longer storability and longer shelf life. Longer shelf life helped feed millers even out their HQCP mash supplies and retain better control of their production.

The three medium-scale producers are producing high-quality cassava flour (HQCF), and they source wet peels mainly from their own operations, but they also buy dried peels. The respondents were not sure if they could process more peels than they currently do. An option for expanding operations is to buy wet cake from other producers to process into mashes, but the respondents had no interest in this option being that drying is a major constraint. Nevertheless, these three

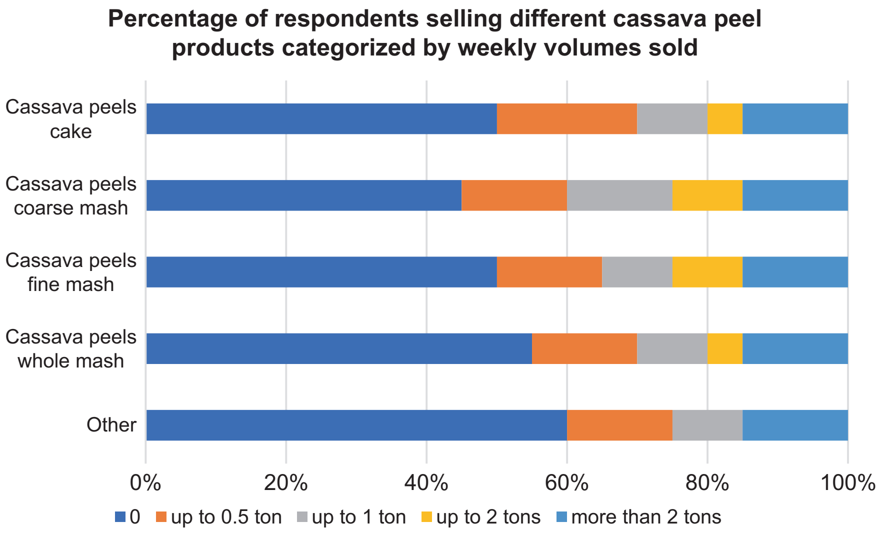


Fig. 6.11 Percentage of the 20 respondents (small-scale processors) selling different cassava peel products categorized by weekly volumes sold. (Source: End of RTB Scaling Fund project survey, 2020)

entrepreneurs plan to expand HQCF production. This development would translate into increased availability of peels, which would expand the HQCP business.

Feed Millers

The four major feed millers who responded to the survey listed several advantages of HQCP, including (1) cheaper than other sources of energy, (2) profitable farmers through reduced feed cost and (3) good source of energy with minimum anti-nutritional factors. They said challenges consisted of (1) low inclusion rate, (2) low crude protein, (3) inconsistent quality and (4) price variation (US$ 125–150). The survey revealed that over 10,000 farmers (mostly fish farmers) have used HQCP products. All of them reported satisfaction with the products, and notably, about one-third of poultry and cattle farmers said they were 'very satisfied'.

Most of feed millers' customers buy poultry and fish feeds. Cattle, small ruminant and other and pig feed clients comprise a small share of the customers (Table 6.8).

Although there was initial reluctance by feed millers, this has been gradually overcome once it became clear that animal production performance remained intact. As such, the incorporation of HQCP in feed has led to increased sales among existing customers and new customers who enjoy lower feed prices. In addition to the 200 tons per week being used by Premier Feeds, up to 520 tons of HQCP is now being incorporated into compound feed by other feed millers every month. This figure is up from 105 tons per month in 2018. Each factory uses different suppliers, but the most reliable supply is through vertical integration (e.g. a cassava flour mill company with a line for HQCP production). All responding feed millers expect to

Table 6.8 Clientele of feed millers that incorporate HQCP mashes by type of feed purchased

Type of feed	No. of clients
Fish	10,132
Poultry	226
Other	21
Cattle	8
Pig	2

Source: End of RTB Scaling Fund project survey, 2020

double their use of HQCP by the end of 2020 barring constraints related to availability, machines for processing, price and consistency in quality and availability. Using more HQCP will lower feed costs and increase factory throughput.

6.5.3 Development Outcome 3

Twenty-five HQCP investors supported to produce successful, bankable proposals and to set up medium to large-scale factories employing youths and women.

The project team developed templates for business plans, including content such as business profiles, vision making and people, business strategy and structure, communication and Information and Communication Technology (ICT) infrastructure, location criteria, operations management strategy, financials and costing, and a marketing and growth program. Different example business plans were prepared for enterprises operating at four different scales. The templates and examples were shared during a 3-day training organized by the project.

Currently, five loan applications are being processed at the Bank of Industry (BoI). BoI staff were part of the trainings and elaborated the requirements for credit. Unfortunately, the gestation period for obtaining credit from BoI, as presented at the training, was overly optimistic. Credit delivery remains encumbered by requirements for securing the loans. However, BoI is not the only financial institution in Nigeria; the business plans are flexible and could be submitted as part of a loan application elsewhere.

6.6 Lessons Learned for Scaling

This section presents the key lessons learned during the implementation of the scaling project. They are categorized in four learning areas.

Capacity/Competencies

The core innovation was developed based on two drying options suitable to small-scale and household enterprises, namely sun-drying and toasting. When the innovation attracted the interest of medium-scale entrepreneurs, additional drying options had to be explored, such as flash drying, rotary drum drying and cabinet drying. The project team lacked the immediate capacities and competencies to respond. Partnership with Niji Foods and collaboration with CIAT experts were critical to overcome these challenges, pointing to the need for careful selection of appropriate partners.

The 'simplicity' of the technology and the decades of processing cassava into *gari* lured us into complacency ('anyone can adopt it') in selecting the initial batches of trainees without sufficient investigation of their motivations. As it turned out, some were interested in the use rather than the production of HQCP, while others were just interested in marketing the products. These are important motivations, but they could not contribute to achieve HQCP production at scale. Based on this experience, interviews were conducted for selecting properly motivated participants to subsequent trainings and to enlist their help to design the training curricula.

HQCP innovation, which builds on age-long processing of cassava into *gari* and other staples, was expected to be a plug-and-play given the similarity of equipment and processes and the huge demand for alternative ingredients in feed production. With an estimated one million households producing and processing cassava into various products and more than 9000 cassava processing centres in Nigeria, we expected immediate massive uptake, but that did not happen. Uptake is never automatic, even when closely related to an existing (technology) way of doing things. However, it is important to note that, when trained in HQCP processing, persons already engaged in some cassava processing had a higher likelihood to become entrepreneurs and adopt the innovation compared to fresh entrants into the cassava processing business.

Strategizing and Scaling Strategy

The high demand for HQCP products could not be met by the small-scale and household producers initially targeted. Meeting this demand will require increasing the numbers of small-scale processors and involve larger-scale investors as well as product aggregators. However, the longer-term aim should be to industrialize the technology so that single factories with capacity to process as much as 50 tons/day become possible and common. There is sufficient demand for HQCP mashes, and fresh peels are available for all scales of producers to the extent that the participation of one group would not adversely affect the other.

Collaboration/Partnership Related

Partnership was clearly biased towards the private sector with a sprinkling of relevant public agencies. The private sector has been involved since the proof-of-concept stage and has stamped a business attitude on the innovation to the extent that it appears that the private sector is leading those big moves.

Early private sector engagement proved helpful to facilitate scaling. For example, with Amo Byng, we performed a technical and economic evaluation of the products and gained their subsequent open endorsement, when bias against HQCP products was still high.

We should do the same and, where necessary, more of reinforcing private sector involvement, engendering transparency and encouraging product standardization to promote commercialization.

Bundling the core innovation with supporting products and services from partners was beneficial to the scaling progress. For example, the collaboration with Single Spark led to the production of FeedCalculator®, which has increased knowledge in feed formulation and promoted the use of HQCP mashes in livestock rations. Practical evidence that inclusion of HQCP mashes into feed did not affect, and sometimes enhanced, livestock performance boosted the confidence of farmers and feed millers and facilitated adoption, especially in poultry and fish production.

The levels of commitment of different partners differed. The partnership with the Bank of Industry, despite being formalized in a contract, did not result in facilitated access to credit by project participants. While formal arrangements can be useful to define roles and responsibilities of partners, these should not be seen as an indicator of commitment to the partnership.

Intervention

Attention to developing the innovation package by adding complementary elements (e.g. hands-on training in production and best business practices, FeedCalculator®, Cassava Peel Tracker® and economic feasibility models) contributed to attract interest to the core innovation – be it for HQCP mash production, feed formulations, pure buying and selling of HQCP products or any combination of the above. These possibilities meant that some of the critical concerns along the value chain regarding new products were addressed within the innovation package.

Overall, it was clear over the course of the entire exercise that scaling had to be a deliberate and proactive effort. *That is, scaling does not just happen, scaling has to be made to happen*. There were several elements (each of them important on their own) that needed to come together, including financial viability and a facilitating business environment. For scaling to happen, each of these elements should be conceptualized not as abstract entities but as having a human face, manifested as interest groups (stakeholders). At this point, one should ask whether these stakeholders desire goals they cannot achieve without certain, mutually beneficial partnerships. If this condition exists, the next step would be to continue to use available, non-costly media to do the groundwork to highlight opportunities created by the technology. Hopefully, this work will arouse different interests and suggest avenues for meeting each other's needs and facilitating agreements that promote commerce. In addition, scaling champions need to follow the positive vibes and remain flexible. There are no blueprints for them to follow.

6.7 Conclusions

Successful scaling requires that the core innovation itself must be easy to use and profitable, like the cassava peel dryers for making HQCP mashes. In this case, the raw materials (cassava peels) were not only free, but they were also an environmental nuisance. At the same time, the rapidly growing livestock industry was demanding more feed. Using HQCP mashes was a chance to turn waste into wealth by using cassava peels to make top quality animal feed. The main challenge was not the hardware (technology), but the software, especially linking small-scale cassava processors (and a few mid-sized ones) with large-scale feed millers. So far, this new value chain is functioning, but it is too soon to tell if the actors will continue to work together.

Doubts remain but these are not insurmountable:

- Will the new product (HQCP mashes) be profitable along the whole value chain?
- Will mutual mistrust remain in spite of the partnerships? Will the lack of formal credit continue to hamper investment?
- Will feed millers continue to buy from small-scale processors (who are mostly women), or will the factories make their own HQCP mashes or buy them from larger processors?
- Will medium-sized producers be able to keep making a quality product, or will they undermine trust in their goods by making them from carelessly dried cassava peels recovered from processor waste piles?

As project funding has ended, it is expected that the work initiated to encourage SON to list HQCP products and set their physical and nutritional standards will provide the guardrails for production of higher-quality products and eliminate poorer quality ones through market forces. Fortunately, the process is still ongoing within SON even in the absence of the project.

The research and scaling efforts have been worthwhile, starting from scratch and gradually nurturing an industry that is in its infancy. Much progress has been made, but support is still needed – especially to buy equipment after training, to standardize products and to promote and market HQCP mashes.

Collaboration with other projects can trigger interest in adopting the HQCP innovation. For instance, the RUNRES project in Rwanda sponsored a training program for a women group in October 2020. During the trip, a skilled fabricator was coached to manufacture the key HQCP equipment. That group now produces about 3 tons weekly based on sun drying even during the rainy season. Another aspect of future work will be to develop HQCP mashes with higher protein content, for instance, through biofortification, which has shown promising preliminary results. This would likely boost the popularity of HQCP mashes among fish and poultry feed millers. The process ferments cassava waste using selected microorganisms, and initial results are positive and indicate the possibility to reach up to 60% conversion rate from waste to feed ingredient on a dry matter basis (Obadina et al. 2006; Aro 2008; Crécy 2012; Tefera et al. 2014).

This innovation has a huge potential to go to scale, since cassava is an important crop in many other countries besides Nigeria. The HQCP project is applicable in all cassava-producing countries. If the importance of cassava in the agricultural sector were to be followed, the Democratic Republic of Congo, Ghana, Cote d'Ivoire, Senegal and Sierra Leone could be possible candidates to scale to innovation. However, the needs of their feed industry should be carefully investigated.

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