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RESEARCH ARTICLE

INVENTORY OF THE MAIN OPERATIONS AND FACTORS RESPONSIBLE FOR HARVEST, POST-HARVEST AND QUALITY LOSSES OF PADDY AND WHITE RICE PRODUCED BY THE NIGER REPUBLIC RICE TRANSFORMATION COMPANY (RINI)

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ABSTRACT

In Niger Republic, the various investments in irrigation sector have made possible to promote irrigated rice cultivation in the river valley and have increase significantly the production. However little attention is given to harvesting and post-production operations; operations likely to reduce harvest/post-production yields, quality of paddy and white rice after milling. The present study has inventoried the harvest and pre/post-harvest operations that impact the production and quality of paddy and white rice, respectively obtained at the rice-growing perimeter of Toula and produced by the Niger Republic Rice Company (RINI). It consisted of monitoring harvesting activities and that of the RINI factory, through a questionnaire guide, the monitoring of the various operations and the estimation of yield and quality losses registered in farm and at RINI. The results obtained showed that post-production and quality losses of paddy and white rice remain closely linked to the harvesting operations carried out by the farmers, but also to the handling and conditions of the infrastructures and machines intended for processing. The losses due to humidity during paddy storage were also factors favoring the reduction in the quantity and quality of white rice. These results will help improve post-harvesting techniques, with a view to boosting local rice productivity and quality in all producer countries.

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INTRODUCTION

Rice (Oryza sp.) is a cereal mainly grown for its grains and straw that are used in food and feed as well as in industry and crafts (Thibaud and Brondeau, 2001; Issaka, 2013). Indeed, in addition to its direct use in human food, rice grains are used to make alcohol, starch and derivatives, oil, pharmaceutical products, dietary foods, etc. Processing by-products (broken, flour, meal) and straw are used in animal feed, rice husks as fuel, fertilizer ash and straw in the form of litter or raw material for the manufacture of paper pulp or for the manufacture of wall paper (CIRAD-GRET, 2003). With a global production of 509.1 million tons of milled rice, rice is the second most cultivated cereal in the world and is the third most consumed and exported product behind wheat and maize (Kam *et al*., 2017). It serves as a staple food for millions of people around the world and its demand is increasing over the years, especially in Africa where rice importations are intended to cover domestic needs, accounting for 20-30% of the world's rice traded (Khush *et al*., 2005; Seck *et al*. 2012; Oludaré *et al*., 2016). In Niger, rice is the third cereal after millet and sorghum, both in terms of area and production (Faivre-Dupaigre *et al*., 2006; Issaka, 2013). The paddy rice national production is 144 814 tons; it covers barely 20% of rice needs (ME, 2019). The country then remains dependent on importations and climatic hazards causing cyclical food crises. Therefore, research and development programs are being developed to increase national production and achieve food security in the medium term, including rice self-sufficiency (SDRN, 2021). These programs are generally based on aquatic rice cultivation (low-ground and irrigated), which is more productive. Unfortunately, aquatic rice cultivation is marked by strong parasitic pressure, the presence of many enemies of rice cultivation (Issaka *et al*., 2012) and especially the inefficient management of pre- and post-production operations that induce very significant economic losses (Issaka, personal communication); thus annihilating the enormous efforts made. The main pre- and post-production operations include: harvesting (heaping, threshing, and winnowing), transport, drying, storage and processing/machining (Appiah *et al*., 2011). Each of these operations leads to losses in rice production and quality (Houssou *et al*., 2016). Indeed, quantitative losses (4.23% during threshing) but also qualitative in machining (high breakage rate, non-homogeneity of the grains or presence of whitish plate on the machined grains, impurities etc.) are recorded during these operations; indicating that harvesting and post-harvest operations (threshing and drying paddy rice) have a significant impact on the production and quality of rice grains produced (FAO, 2011; Dansou *et al*., 2018). However, the majority of post-harvest cereal losses were only estimates of storage losses (Hodges *et al*., 2014); loss figures for other links in the chain are relatively rare because: (i) loss assessment is usually done at the request of a project to improve one aspect of the post-harvest system and (ii) the difficulty of making post-harvest loss estimates.

Thus, the place usually reserved for post-harvest losses is often minimal and relegated to second place in the face of crop defense where the biology of pests takes precedence over the overall importance of losses (Issaka *et al*., 2012). In addition, (i) post-harvest losses are due to peasant practices and insufficient technical and financial resources of producers and (ii) rice processing techniques are sources of loss of production and quality. This study consisted of inventorying pre-harvest, harvest and post-harvest operations as well as the limiting factors responsible for post-production losses, in order to contribute to the improvement of the productivity and quality of local rice. The aim was to: (i) identify the main operations responsible for these losses and (ii) determine the yield and quality losses of paddy rice during white rice machining.

MATERIALS AND METHODS

Study area: The monitoring and inventory of harvesting and pre- and post-harvest operations as well as those of factors limiting rice production and quality were carried out on the rice perimeter of Toula (Figure 1). Comparative observations of harvesting and post-harvest techniques were also conducted on Daikaina and Daibéri perimeters (Figure 1). As for the monitoring and inventory of machining operations and the factors responsible for the yield and quality losses of white rice, they were conducted to the Niger Republic rice transformation company (RINI).

Figure 1. Location of the RINI and the sites of origin of the paddy rice all-coming (Famalé, Diomana, Diambala, Toulaetc)

Study materials: The inventory of harvesting and pre- and post-harvest operations as well as the factors responsible for post-production and rice quality losses was conducted on the basis of: (i) a questionnaire on pre-harvest/harvest and post-production methods of paddy rice addressed to producers and cooperative managers and (ii) observations and assessments made in the rice fields and at the RINI. The plant material used is paddy rice all-coming from Toula and other perimeters (Famalé, Diomana and Diambala) which serves as raw material for RINI camapany white rice production; the paddy consists largely of the grains of the varieties IR1529-683-1 and Kogoni 90-1, mostly sown in rice fields. RINI equipment (gloves, face masks, blower, scale, etc.) and other materials were also used.

Data collection and analysis: The study consisted of: (i) questioning producers in the Toula perimeter about their pre-harvest, harvest and post-harvest practices; (ii) monitor, observe and inventory harvesting and pre- and post-harvest operations in rice fields during the days of such activities; (iii) monitor and inventory the handling and machining activities of the RINI and (iv) analyze and process the information collected, using Excel and Arc-Gis. Thus, a prospection was conducted on the rice site of the study. It consisted in identifying and inventorying the main harvesting and pre- and post-harvest operations of paddy rice as well as the factors of production and quality losses of rice. To inventory these operations and the factors responsible for the losses, two hundred and forty-five (245) producers out of the 975 in the scope were sampled, i.e. 25% of the operators. The first step was to inventory the various pre- and post-production operations identified by the producers themselves.

A survey sheet for farmers helped to collect information on harvesting and post-harvest operations as well as the factors responsible for rice production and quality losses. Then, direct observations and field studies were carried out to both verify the information gathered during the interviews and discuss the role(s) of these operations and factors. The estimate of rice production and quality losses involved three (3) pilot producers (A, B and C) in whom harvest and post-harvest operations were monitored (Table 1); Farmer A respecting good pre-harvest, harvest and post-harvest practices and minimizing the factors responsible for losses in rice production and quality. The maximum and minimum recorded rice production and quality losses were obtained by comparing the estimated losses at pilot producers B and C and control (model) A. To record yield and quality losses during the transformation process, handling and machining operations, the inventory of factors responsible for losses as well as the state of the RINI infrastructure were monitored, analyzed and assessed. Thus, the following formula made it possible to calculate the rate of impurities (in percentage) contained in the all-coming paddy from the supplying cooperatives (Dansou *et al*., 2018):

$$\% \text{ Impurities} = \frac{\text{PI} \times 100}{\text{PIP}}$$

(With: PI= weight of impurities and PIP: initial weight recorded)
All the results from the observations on infrastructures made it possible to understand the role of infrastructures on the decline in productivity and quality of white rice produced by RINI. The quantities of broken rice were assessed on a sample of five bags of rice. The breaks obtained during the bleaching of the cargo rice were extracted and weighed per bag and the rate of breakage was calculated according to the following formula:

$$\text{Rate of breakage} = \frac{\text{Amount of breakage}}{\text{Total amount of bran}} \times 100$$

RESULTS

Farmer's perception of the role(s) of pre-harvest, harvest and post-harvest operations on paddy production and white rice quality: The farmer survey revealed four (4) levels of rice production and quality losses between the farmer plot and the RINI Company (Table 2). These are losses due to pre-harvest, harvest, post-harvest operations and the factors favoring such losses. Overall, in wet season, the losses in rice production and quality during harvest, post-harvest and pre-harvest operations were respectively estimated at 56.33%, 16.33% and 13.06% (% of respondents with favorable opinions) when, in the dry season, these losses represent respectively 54.29%, 15.10% and 12.24%. However, the factors responsible for paddy and quality losses recorded were about 18.37% in dry season and 14.29% in the wet one. Losses due to threshing/winnowing (32.65%), heaping/pre-drying (14.29%) and drying (8.16%) were most in the wet season, followed by the effects of birds/animals (08.16), humidity (6.12%), pre-harvest drainage (6.12%), storage/conservation (5.71%), and sorting (2.04%). However, according to respondents, machining losses recorded were less than 1%.

Estimation of rice production/quality losses and results of direct field observations among pilot farmers: The results of the assessment and quantification of certain parameters of production and quality of the pilot producers' harvests (Table 3) indicate, on the one hand, that model producer A obtained the best harvest (18 bags of paddy) and clean production (little impurities and losses) and, on the other hand, that farmers B and C, who did not apply good pre-harvest practices, harvest and post-harvest recorded a certain percentage of losses in rice production and quality.

Table 1. Description of pilot producers

Producer A	Producer B	Producer C
Clean plot (clean)	Parcelle enherbée à 50%	Parcelle 100% enherbée
Drainage 48 hours before harvest	Drainage 24h avant récolte	Non drainage
Harvest at maturity	Récolte à la semi-maturité	Récolte échelonnée
Heaping	Heaping	Heaping
Secure pre-drying	Direct threshing	Pre-drying on dike
Batting on barrel / tarpaulin	threshing with stick / tarpaulin	threshing with stick / mats
Manual winnowing on tarpaulin	manual winnowing on mats	manual winnowing / threshing area
Drying/sorting before sacking	Sorting direct sacking	Direct sacking
Transport by car	Transport by tricycle	Transport by cart

Table 2. The main pre-harvest, harvest and post-harvest operations and factors responsible for rice losses and quality by farmers

Types of operations	Score Dry season losses (SS)	Wet Season losses (HS)	SS losses (%)	HS losses (%)
Pre-harvest operations:	**30**	**32**	**12,24**	**13,06**
Condition of the plot	3	5	1,22	2,04
Maturity level	4	2	1,63	0,82
Pre-harvest drainage	8	15	3,27	6,12
Harvest period	3	7	1,22	2,86
Securing plots	12	3	4,90	1,22
Harvesting operations	**133**	**138**	**54,29**	**56,33**
Harvest	5	3	2,04	1,22
Heaping / Pre-drying	35	35	14,29	14,29
Threshing / Winnowing	75	80	30,61	32,65
Drying	18	20	7,35	8,16
Post-harvest operations	**37**	**40**	**15,10**	**16,33**
Transport	3	3	1,22	1,22
Storage/conservation	15	14	6,12	5,71
Drying	12	16	4,90	6,53
Sort	5	5	2,04	2,04
Machining	2	2	0,82	0,82
Favorable Factors of losses	**45**	**35**	**18,37**	**14,29**
Granivorousbirds/animals	20	2	8,16	0,82
Humidity	15	20	6,12	8,16
Impurities	7	10	2,86	4,08
Condition machining	3	3	1,22	1,22
Total/percentage of respondents	**245**	**245**	**100,00**	**100,00**

Table 3. Status of paddy production and quality losses among pilot producers

Features of the paddy	Producer A	Producer B	Producer C
Paddy quality	Clean paddy	Presence of moldy grains	Mixed paddy
Impurities	negligible	5%	4%
Harvest obtained/ 0,25Ha	18 bags	16 bags	14 bags
Paddy losses	Negligible	2 bags	4 bags

Figure 2. Moldy (A) and germinating (B) paddy

Table 4. Collection of paddy losses due to poor storage

Date	Quantity of machined paddy (Kg)	Quantity of paddy lost (Kg)
June 11, 2020	130060	18.7
June 16, 2020	124994	20.8
June19, 2020	125466	14.3
June 23, 2020	126050	19.2
June26, 2020	129056	21
June, 28, 2020	129410	17.6
July 01, 2020	127605	16.5
July 02, 2020	125107	19.8
Total	101 7 748	147.9

Figure 3. Paddy bags with holes on carts and paddy grains poured on to the sidewalk

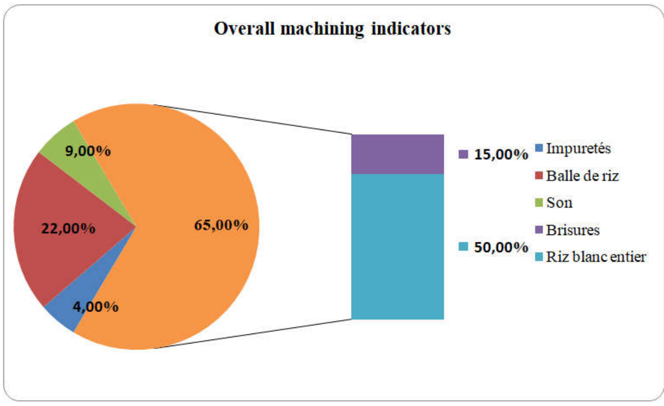

Figure 4. Over all machining indicators

Figure 5. RINI bleaching sieve, in poor condition

Figure 6. Using the Sound Blower

Table 5. Impurity levels recorded by cooperative

Cooperative	Famalé	Diomana	Diamballa
Paddy weight (kg)	48 647	129 056	20 284
Weight of impurities (kg)	2 095	4 570	1 067
Impurity level (%)	4,3	3,54	5,6

Average impurity/machining rate 4,48 %

Table 6. Quantities of broken bran in Kg

45 kg bran bag	Bag 1	Bag 2	Bag 3	Bag 4	Bag 5
Amount of breakage (Kg)	5.3	6.4	4	6.4	4.6
Total quantity of Breaks (Kg)	26.7 / 225 (11.86%)				

Indeed, the harvest of the farmer B, in addition to the losses of about 2 bags of paddy, contains 5% of impurities (pebbles, other grains and seeds ...) and moldy grains (Figure 2). That of the farmer C, meanwhile, is marked by strong production losses (4 bags) and the paddy mixed, with a large moldy (Figure 2A) and sprouted part (Figure 2 B).

Results of the monitoring of harvesting and post-harvest operations on the Toula, Daikaina and Daiberi perimeters and at the RINI Company: Harvesting operations were monitored throughout the period, through direct observations. It appears that the harvest is done manually with a sickle or with a mower at the full maturity of the plants, determined empirically (the grains loaded on the panicles are hard to the touch, their color is yellowish with a pronounced sense of smell, etc.).

The producers do not use the moisture meter to assess the moisture content of grains and to detect the ideal temperature for good harvest. Manual threshing of panicles is carried out directly after harvest at the entire study sites. It is direct and is done without pre-drying, using barrels, tarpaulins (intact or holed), mats and sticks. The pre-drying of panicles is sometimes practiced there. However, some producers practice pre-drying of standing grains; pre-drying consisting of drying the panicles on site in order to reduce the water content of the rice grains and bring it back to the optimum level of threshing (water content of 12%). Harvesting and threshing operations are not mechanized and the delivery of the paddy to the drying place remains difficult, due to lack of means of transport. The paddy is dried in drying areas to reduce the water content of the grains between 14 and 12%. This operation is mainly characterized by the phenomenon of desiccation and moistening of the grains.

Indeed, in case of high humidity of the paddy it is observed the growth of mold on the milled rice and during drying at a high temperature the cracking of the grains increases. The conservation of paddy rice grains is therefore conditioned by the water content of the grains during storage. However, large quantities of paddy are often stored in bags by farmers in poor storage conditions, before they are transported to the cooperative and then to the RINI Company. Losses of 14.7 Kg of paddy were even recorded on the contents of the hopper or pit (25 paddy bags of 72 Kg each). Table 4 gives the results of quantifying losses due to poor preservation at one of the RINI paddy storage stores, over a period of one month (time required to empty the store) and for nine (9) days chosen at random. Productivity losses vary, per day, between 16 and 21 Kg of paddy. Thus, during the period of one month alone, it was recorded up to 147.9 Kg of paddy (moldy or sprouted) lost corresponding to 100 Kg of white rice, if we consider the average machining rate of 67%. The wide variation in losses over time and days is related to the fact that paddy from a cooperative comes from several producers who use different experiences, practices and storage areas.

Results of the monitoring of handling and machining operations at the RINI Company

Paddy handling results: During the movement of paddy bags from the stores to the machining room, the following constraints were identified: (i) the non-collection of paddy grains that fall from bags with holes during transport by trolley; (ii) increased grain losses with the many cart towers; (iii) the lack of permanent care in handling activities, which leaves a large number of Kg of paddy on the sidewalk (Figure 3).

Qualitative losses of paddy in machining: Machining or shelling consists of separating the bales from the cargo rice. The paddy first went through the pre-cleaner to remove all foreign bodies; this made it possible to inventory and quantify the impurities obtained. The impurities identified include grains of sand, grains of clay, stems, rice straws and pebbles, which account for an average of 4.48% (Table 5). Table 5 gives the proportions of impurities recorded at the level of the cooperatives that supply the RINI Company. The levels of impurities varied between 3 and 5.6% depending on the cooperatives from the paddy; these impurities are due to bad post-harvest practices that remain archaic at the cooperative level. Indeed, the operations of harvesting, heaping and threshing are most often done in conditions that expose the paddy to any kind of foreign body (impurities). The paddy bags of 72 Kg admitted to the RINI Company are properly stored in stores at the optimum machining temperature. However, holes in bags scattering paddy grains on the ground are often observed.

Qualitative and quantitative losses in cargo rice milled: Bleaching consists in bleaching cargo rice; it separates white rice from bran. During bleaching important quantitative and qualitative losses are recorded. These were, most often, qualitative losses of raw material (paddy), poor packaging, unbalanced drying of moisture, threshing with a large number of cracks of the grains that increase the quantitative losses of the broken grains. Qualitative and quantitative losses are recorded using global machining indicators. The indicators recorded during the study are: (i) 65% machining yield rate (15% broken and 50% whole white rice 32 and 33), (ii) 22% rice husks, (iii) 9% rice bran and (vi) 4% impurities (Figure 4). The yield or machining rate depends on the quality of the paddy and the condition of the machines. This efficiency is 65% if the paddy is of good quality and the machines are in best condition. However, it can drop by up to 60%, if the quality of the paddy is poor (immature paddy grains, high level of impurity, cracked grains during threshing operation). In addition, the bleaching of cargo rice causes quantitative losses in fine breaks. Indeed, this operation releases in the bran, in addition to the flour, a large amount of broken grains called fine breaks; fine breaks constituting lost grains. These losses are related to the quality of the paddy and especially to the state of obsolescence of the sieves to be bleached (Figure 5); the mesh of these sieves being regularly cobbled together by worn fabrics, due to lack of maintenance. Figure 6 shows the method of identifying these lost breaks at the level of the cone to be bleached. It consisted of using a blower to release the bran of the broken grains. Table 6 shows the quantities of broken stock extracted and weighed per bag on a sample of five bags. A total of 26.7 Kg of breakage is lost within 225 Kg of bran; i.e. 11.86% of quantitative losses recorded during the operation.

DISCUSSION

From the peasant plot to the RINI Company, farmers argued that losses due to harvesting, threshing/winnowing, post-harvesting and heaping/pre-drying operations are greater in the wet season when these operations coincide with the work of the dune fields, under limiting humidity and environmental conditions. Also, the factors favoring the losses of paddy and quality of the milled rice are more preponderant in the dry season where the pests have only rice as a source of food. However, the farmers felt that the machining has very little impact on the quality of the white rice produced by the RINI Company. These main operations and factors of harvesting and post-harvesting were previously identified as main responsible of paddy production and quality losses (CORAF/WECARD, (2011; Appiah *et al*., 2011). So, good practices like: (i) the purification of the plot before harvest, (ii) the drainage of the plot 48 hours before harvest, (iii) the heaping / pre-drying in a dry place, (iv) threshing / winnowing with equipment limiting grain losses, (v) drying on appropriate area / sorting before bagging and (vi) safe transport to the RINI were very useful to minimize the rice losses during harvest and post-harvest operations. The roles of these operations and factors were reported for the first time in Niger republic. Field observations have indicated that harvesting requires cleanliness of the plot, maturity at 80% of the panicles, pre-drainage and harvesting tools, threshing and winnowing by using tarpaulins without holes. The results showed that the determination of the maturity of the fields is empirical because essentially based on the smell, the shape of the panicles, the appearance and color of the grains etc. Also, the plots are rarely purified, which leads to a high level of impurities related to the presence of grains and seeds of other plant species. As for pre-drying and drying, they are carried out without using the moisture meter. This does not guarantee a good humidity level for optimal drying. Similar conditions and practices have been obtained by CORAF/WECARD (2011) who reported that the appropriate time for rice harvesting is when 80% of the panicles have reached full maturity, with fully ripe grains and a moisture content of between 20 and 22%; the grain being white and hard once the shell is removed.

Threshing is manual at the study sites. This is tedious and could leave unshuffled grains on the straw and or grains poured on the ground and mixed with foreign bodies. These results are in harmony with those of Dansou *et al*., (2018) having indicated that in Benin manual threshing is slow and gives a low yield while promoting the contamination of paddy by sand, pebbles, immature grains and other external materials; this operation leads to a reduction in general production. In addition, according to Dansou *et al*., (2018), manual threshing causes average losses of 4.55% of paddy and impurity levels of 3.1%. Direct threshing, without pre-drying and on tarpaulins with holes, leads to strong losses in grains (leaves grains on the beaten panicles and during collection) and degrades its quality (increases the cracking of grains, paddy mixed with rice straw, clay, small pebbles etc.). In addition, quantitative losses of paddy are recorded as a result of the propulsion of the grains during the mechanical action of threshing. These results are consistent with those of Dansou *et al*., (2018). The pre-drying of standing grains promotes the pouring of panicles and losses of paddy grains even before harvest. As for the drying of paddy on drying areas, it significantly impacts the quality of machined paddy, because of the phenomenon of desiccation and moistening. Thus, improper drying at high humidity of the paddy promotes the growth of mold on the machined rice and drying the paddy at a high temperature increases the cracking of the grains. This greatly affects the quality of the milled rice. To avoid obtaining a moldy paddy, it is recommended a controlled drying of the grains in the hot afternoon sun for 2 to 3 hours (stirring them from time to time), followed by their drying in the shade (Appiah *et al*., 2011). Also, the phenomenon of grain cleavage observed in this study was previously reported by Cruz *et al*., (2019) during rapid drying. Still according to Cruz *et al*., (2019), the phenomenon of grain cleavage can also take place in the field with precipitation following a dry wind, or the succession of very sunny days by wet nights marked by strong morning dews; such conditions prejudicial to the good industrial behavior of grain. Quantitative losses of 2.35% of paddy grains during drying in the sun and in the open air were obtained Dansou *et al*., (2018).

The losses recorded here are on the one hand, lower than those resulting from the work of Rembold *et al*., (2011) which were estimated losses at 6.9% and on the other hand, higher than those obtained by Oguntade *et al*., (2014). Losses due to drying are generally related to the use of torn tarpaulins and/or the lack of suitable drying area infrastructure (Sarr *et al*., 2013). Heaping, pre-drying and drying in conditions of high humidity promote the achievement of significant proportions of moldy paddy grains. This suggests that it is very important to separate the paddy from the soil contact with pallets, in order to avoid the rise of soil moisture and grain rot. In-store storage helps maintain acceptable moisture before machining. Similar results were obtained by Andriamparanony *et al*., (2011) who estimated that the poor storage practiced by farmers, without perfect control of the optimal temperature, contributes to the increase in the loss rate of up to 4% of village community granaries. Also, the results obtained by Ramaratsialonina *et al*., (2016) have shown that incomplete maturation of products, insufficient drying on the field or at the exit of the field, storage of products still wet cause significant mold problems; the available water allowing bacteria, yeasts and molds to grow and thus increase the alteration of the grain that serves as their substrate. This corresponds to the results of a poor organization of the storage attic (mold in contact with the ground and bags disemboweled by broken woods). Our results suggest a lack of paddy storage/drying infrastructure at the farmer level. Indeed, the storage conditions are rudimentary, applied with negligence and allow storage losses to grow.

Qualitative and quantitative losses in paddy rice production: After threshing, the rice must be cleaned and valved to remove all foreign bodies (organic and inorganic matter), i.e. impurities; the latter being estimated at 4%. These results differ from those of Houssou *et al* (2016) who recorded impurity levels of around 3.1% while establishing a close link between the high level of impurity and manual threshing. Indeed, manual threshing is most often done with defective tools lets the beaten paddy drag on the ground, in contact with the ground, clay and straws. This suggests that paddy is mixed with impurities. This whole chain of operations requires much more time and manpower. However, it is often poorly executed and the paddy arrives at the RINI Company with a high rate of undesirable elements that increase qualitative losses. Our results also reveal a lack of material and technical means to help producers to reduce the level of impurities present in the paddy before machining / marketing. The presence of immature paddy grains, many impurities and cracked grains during the threshing operation and the condition of the machines of the RINI plant vary the milling efficiency of the rice.

Thus, the company's overall forecast indicators give a machining efficiency of 65% vs 70% according to Cruz *et al*. (2019). Indeed, these authors reported that: (i) rice husks account for about 20% and bran 10%, (ii) machining efficiency is potentially close to 70% with a shelling efficiency of 80% and a bleaching yield of 87.5%; These two results differ, on the one hand, in the quality of the paddy and on the other hand, in the mechanical action. This suggests that the industrial quality of rice depends on both the proper conditioning of the paddy before machining, the balanced drying of the humidity (respect for the appropriate temperature) of threshing and machining of the paddy. The quality of rice is also function of threshing with less mechanical pressure; which reduces the number of cracks in paddy grains. The dilapidated state of the sieves to be bleached and the supply of all-coming paddy (consisting of a mixture of all kinds of varieties from the cooperatives supplying paddy to RINI).

Our results are identical to those of Cruz *et al*. (2019) who suggested that grain breaks are due to both the mechanical action of machines on the grain and the phenomenon of cleavage of the grains during their development in the field or during drying. The advent of breakage is also linked to the quality of the paddy which is dependent on good pre-harvest, harvest and post-harvest practices. The industrial quality of rice also depends on the climate during grain ripening and the climatic conditions of the period of early ripening-harvest of rice; their effects are greater than those caused by the shocks received by the grains during threshing and machining. Dansou *et al*., (2018) recorded average paddy losses of 5.2% during machining, after traditional drying (sun drying) of panicles; indicating that the breakage rates (29.8%) obtained by husking paddy rice grains dried by this method are significantly higher than those of paddy grains dried with the mixed method (24%). This technology is based on the determination of the moisture content of the grain, practiced by farmers; the optimal moisture content of the grain at harvest is between 20 and 25%. The results of observations made on the condition of the sieves and the non-homogeneity of the paddy to be machined suggest that these parameters must be mastered in order to better reduce losses by fine breakage; machining is a source of loss if the condition of the machines used to transform the paddy remains obsolete or if the sieves spend much longer than expected before being changed. These aforementioned results deduce the obtaining of rice milled with a lot of breaks and generate many fragments or fine breaks in the bran.

CONCLUSION

The results obtained revealed a lack of attention in the conduct of pre-harvest, harvest and post-harvest operations as well as limiting factors. These operations and factors greatly influence the production and quality losses of paddy and milled rice. The most impactful are: (i) manual harvesting, threshing/winnowing, piling/pre-drying/drying and (ii) factors favouring losses such as high humidity/temperature during storage, the effects of birds and animals, the careless handling of the paddy and the defective and dilapidated condition of the machines as well as (iii) the quality of the paddy to be machined. These operations and limiting factors of rice production and quality then deserve to be improved by: (i) the use of good harvesting and pre/post-harvest practices, (ii) the improvement of RINI's technical infrastructure and drying, threshing / winnowing techniques and (iii) the development of new appropriate technologies; this will help to boost the productivity and quality of rice produced.

CONFLICTS OF INTEREST: The authors state that there is no conflict of interest.

AUTHORS' CONTRIBUTIONS

IS, NI implemented the protocol, conducted prospecting and sampling, set up bioassays, collected, analyzed and interpreted the data. MAD and SMAM contributed to sampling, trial conduct, and data analysis and interpretation. All authors wrote and corrected the manuscript before and after submission.

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