Design and Testing of Improved Village-Type Dehuller- Degerminator for Dry-Milling Process of Corn

Michael A. Gragasin, Romualdo C. Martinez

Abstract—Majority of the available village-type corn mills in the Philippines have failed to fully satisfy the minimum product recovery and degerminator efficiency of 64% and 80%, respectively, as set by the Philippine Agricultural Engineering Standard (PAES). This resulted in the production of poor quality corn grits with high postharvest losses. Vital in improving the performance of existing village-type corn mills is the development of efficient dehuller-degerminator that responsible in the separation of germ and hull including the tip cap from the endosperm. The major part of the corn kernel that causes irritation when cooked corn grits are served in the table is primarily the tip cap and not the hull alone. The results of laboratory and field trials revealed that the developed dehuller-degerminator has a milling capacity of 367 kg/h and capable of providing milling recovery of 79.2% and degerminator efficiency of 83.8%. Significant reduction in aflatoxin level was also observed once corn kernels with high level of aflatoxin have pass through the developed dehuller-degerminator. The innovative design features a hexagonal-dented screen-huller with counter-flow auger and suction blower to efficiently separate the tip cap, germ, and hull from the endosperm.

Index Terms - Corn dehuller-degerminator, Corn mill, Dry-milling process, Postharvest.

I. INTRODUCTION

Corn is the staple food of 15% of the total population in the Philippines [1]. Village type corn mills are widely used in the production of corn grits. The bran, which is composed of germ and hull is utilized for animal feeds.

A kernel of corn is comprised of four main parts, namely: pericarp (also referred to as hull), germ, tip cap,and the endosperm [2]. The process of removing and separating the pericarp and germ including the tip cap from the endosperm is known as degermination and the main product is called degerminated corn or "cracked corn" as commonly known in the Philippines. Corn grits are milled corn kernels where the pericarp, germ and tip cap are removed and with particle size of not less than 0.86 mm [3].

The performance of the corn mills has adversely affected the supply and demand of corn grits in the Philippines. The Philippine Agricultural Engineering Standard (PAES) for corn mill requires the performance of a corn mill to have a minimum *degerminator efficiency* of 80% and *main product recovery* of 64% [3]. Lower *degerminator efficiency*than the standard indicates the production of poor quality corn grits given the high presence of pericarp and germ in the product, Likewise, a lower*main product recovery*than the standard indicates the high incidence of postharvest losses during milling.

The poor quality of corn grits and the lack of available corn mills are some of the major factors that contribute in the diminishing consumption of corn grits in the Philippines [1]. Most of the village-type corn mills have failed to meet the minimum quality standard for corn mill particularly the minimum *degerminator efficiency* and the *main product recovery*. Majority of these village-type corn mills have a milling capacity of 120-200 kg/h. Its primary design is based on the principle of dry-milling process which is a modification to the dry-milling method [4] due to the omission of tempering of corn kernels before dehulling or degermination process.

As evident, the inefficiency of available corn mills can be easily detected through the milling fee being charged by corn mill operators all throughout the country. The current milling fee of Php2.25-3.00/kg (US$1=Php45) is based on the total weight of input of corn grain being milled, which is equivalent to Php3.50- 4.70/kg if based on the total weight of corn grits milled by the machine assuming a milling recovery of 64%. This is contrary to the practice being carried out by the rice millers where the milling fee is based on the output of the rice mill and not on the total weight of input or the total weight of paddy being milled. Note that the milling fee being charged by rice millers in the Philippines only ranges from Php1.75-2.25/kg. As such, the corn traders either buy white corn from the farmers at low price or sell corn grits to the consumers at high price or the combination of both to recover the losses and the high cost of milling.

Reference [5] emphasized that the basic features of a corn degerminator are the following: high yield of grits in the degerminator product stream particularly flaking grits, minimum fines production, good degermination and dehulling i.e., good release of germ and hull from the endosperm, minimum grinding of the released germ and hull, minimum operator attention, minimum maintenance, high capacity, and low power requirement.

As such, vital in improving the technical performance of village-type corn mills in the Philippines is the development of efficient dehuller-degerminator to ensure the production of good quality corn grits while maintaining high product recovery to promote the wider consumption of corn as one of the major staple food in the country.

II. METHODOLOGY

A. Conduct of field interview with corn grits consumers

Field interviews in major corn eating areas were conducted in Visayas and Mindanao regions in the Philippines to determine the issues and problems confronting

Revised Version Manuscript Received on October 26, 2015.

Michael A. Gragasin, Agricultural Mechanization Division, Philippine Center for Postharvest Development and Mechanization (PhilMech), Department of Agriculture, Science City of Munoz, Nueva Ecija, Philippines.

Romualdo C. Martinez, Agricultural Mechanization Division, Philippine Center for Postharvest Development and Mechanization (PhilMech), Department of Agriculture, Science City of Munoz, Nueva Ecija, Philippines.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

the current quality of corn grits available in the market. Among the information gathered were the following: preferred size of corn grits, how they wash and cook corn grits, opinion on what makes the corn grits of good and bad quality, where they mill their corn produce in case they are farmers, cost of milling, buying price of corn grits, and others. This information has served as basis in designing the features of the dehuller-degerminator.

B. Evaluation of existing village-type corn mill

Existing corn mills specifically designed in the production of food were identified for characterization and evaluation. During the conduct of evaluation, the strength, weaknesses and functionality of the current designs of the different componentsof corn mills, i.e., degerminator, milling, grading, were fully observed. The results of the performance testing individually conducted by the Agricultural Machinery Testing and Evaluation Center (AMTEC), University of the Philippines on these corn mills have also served as reference during the conduct of evaluation. Under Philippine Law, AMTEC is a duly recognized and independent body that conducts testing of agricultural machineries.

Corn samples used during the testing were limited to 5 kg of hybrid white corn variety and for one trial only due to the limitation of available samples that were brought in the different test areas in Luzon, Visayas and Mindanao where these corn mills were located. Corn mills tested have a milling capacity of 120-160 kg/h.For all the test trials conducted, the same variety was used and originated from the same lot.

C. Design and fabrication

The concept of the new design of dehuller-degerminator was drawn through AutoCAD featuring its detailed parts and components. A laboratory small-scale model was first fabricated and tested in the PHilMech fabrication shop to determine the performance of such new design under laboratory condition. Debugging and modifications were conducted on the different components of the proto-type laboratory unit until the desired performance of the dehuller-degerminator was achieved particularly on the quality and quantity of corn grits produced.

Upscale model of the final design of the dehuller-degerminator including its different parts and components were redrawn through AutoCAD. The AutoCAD drawings have served as reference in the fabrication of the final prototype unit and to clearly visualize the initial design of the dehuller-degerminator in three dimensional perspectives. The fabrication of the different parts and components of the dehuller-degerminator were all likewise undertaken at the fabrication shop of PHilMech.

D. Performance testing

The technical performance of the dehuller-degerminator was evaluated following the Philippine Agricultural Engineering Standard - Method of Test for Corn Mill[6]. The parameters and formula used in establishing the performance of the dehuller-degerminator were as follows:

Input Capacity (kg/h)

$$= \frac{Weight\ of\ corn\ kernel\ input\ (kg)}{Total\ loading\ time\ (h)}$$

Output Capacity (kg/h)

$$= \frac{Weight\ of\ main\ product\ \ (kg)}{Output\ time\ (h)}$$

Milling Capacity (kg/h)

$$= \frac{Weight\ of\ corn\ kernel\ input\ \ (kg)}{Total\ operating\ time\ (h)}$$

Main Product Recovery(%)

$$= \frac{Weight\ of\ main\ product\ (kg)}{Weight\ of\ \ input\ (kg)} x100$$

Main By-product Recovery(%)

$$= \frac{Weight\ of\ \ by-product\ (kg)}{Weight\ of\ \ input\ (kg)} x100$$

Electrical Energy Consumption (kWh)

$$= Power\ consumed\ (kW) x\ Time\ operation\ (h)$$

The duration of each trial started with feeding of corn kernels in the intake hopper and ends after the last discharge from the output chute. The speeds of the rotating shafts were monitored using a tachometer. A digital clamp meter was used in monitoring and measuring the voltage and electric current during operation, while an electric meter was used in measuring the amount of electric energy consumed.

E. Laboratory analysis

The main product as well as the by-products of the developed dehuller-degerminator was analyzed in the laboratory following the laboratory method of test for corn mill[6]. As set by PAES, three samples weighing 100 grams each were collected from the dehuller-degerminator outlets for laboratory analysis. The laboratory analysis was undertaken to determine the *degerminator efficiency* of the machine. *Degerminator efficiency*, is the ratio of the weight of degerminated corn kernel sample, to the initial weight of the sampleexpressed in percent [3].

The developed dehuller-degerminator was also tested on its capability to reduce aflatoxin content of corn kernels. Aflatoxins are toxic secondary metabolites produced by fungal strains of the genus *Aspergillus* namely: *Aspergillus flavus, Aspergillus parasiticus and Aspergillus nomius*[7]. Contamination of corn and other food commodities with aflatoxins is a public health concern because of the ability of aflatoxins to cause human and animal diseases and have been implicated with acute and chronic aflatoxicosis, genotoxicity, hepatocellular carcinoma, suppression of the immune system, aggravation of kwashiorkorand impaired childhood growth [8]. PHilMech study revealed the high incidence of aflatoxin contamination of majority of corn samples collected in the field [9]. As such, it cannot be avoided that the harvest of farmers especially during the “wet-rainy” season are contaminated with aflatoxin with level higher than 20 ppb, the allowable limit for food. The aflatoxin analysis was undertaken by the Laboratory Services Division of PHilMech using the High Performance Liquid Chromatography (HPLC).

F. Experimental design and statistical analysis

The data gathered were consolidated and analyzed using Analysis of Variance (ANOVA) to determine the differences among group means on the different design and technical parameters of the developed dehuller-degerminator. Each test trials had two repetitions while the collection of samples for laboratory analysis had two replicates. Statistical analysis was performed using Statgraphics Plus, a statistic package software that performs and explains basic and advanced

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

statistical functions.

III. RESULTS AND DISCUSSION

A. Benchmark data for the design

As a start, the results of performance tests conducted by AMTEC were used in analyzing the strength and weaknesses of the current design of village-type corn mills in the Philippines. As evident in Table1, all of the village-type corn mills tested by AMTEC did not satisfy both the minimum *degerminator efficiency* and the *main product recovery* of 80% and 64%, respectively, as prescribed in PAES 210:2000. These corn mills have featured a two-stage dry-milling process using different degermination mechanism, namely: steel huller, emery stone, and attrition type hullers. Note that the brand names of these corn mills were withheld and instead named as Cornmill A, Cornmill B, Cornmill C, and Cornmill D to protect the interest of the supplier or manufacturers of these corn mill machines.

TABLE I. PERFORMANCE TEST RESULTS OF CORN MILLS CONDUCTED BY AMTEC

Performance Parameter	Cornmill A	Cornmill B	Cornmill C	Cornmill D
Output Capacity, kg/hr	128.8	52.0	88.2	97.5
Milling Capacity, kg/hr	200	125.6	120.0	161.3
Main Product Recovery, %	64.4	39.4*	73.5	60.5*
Degerminator Efficiency, %	76.7*	100	45.6*	44.0*
Power/fuel Consumption	3.06kW	1.32l/h	2.52kW	1.55l/h
Labor requirement, persons	2	3	2	2

* Below the minimum standard set by PAES

As evident in Table 1, Cornmill B ensures the production of good quality corn grits given a high *degerminator efficiency* of 100% but with very low *product recovery* of 39.4%, far below the prescribed minimum *main product recovery* of 64%. The result indicates that by using this type of corn mill, a total of 23.6% of the total output are lost during milling operation alone. Likewise, the test results revealed that while Cornmill C can provide higher *main product recovery* of 73.5%, it has a very poor *degerminator efficiency* of only 45.6%, thus, 54.4% of the total product still have germ or hull present in the corn grits. The results of AMTEC tests clearly indicate that there is a trade-off between *main product recovery* and *degerminator efficiency*, i.e., a high *main product recovery* would result to lower *degerminator efficiency* or poor quality of corn grits, while a very high *degerminator efficiency* would result to low *main product recovery*.

During the conduct of actual evaluation, it was observed that all of the corn mills have similar basic components. These include the dehuller-degerminator assembly, corn grits milling assembly, and the grader assembly. For the dehuller-degerminator, they used emery stone and steel huller to separate the pericarp, germ, and tip cap from the endosperm.

The common problems of the existing corn mill designs were the following: (i) Difficulty in starting the engine especially if it is already engaged to the major components of the corn mill; (ii) Low output capacity of the corn mills; (iii) Poor quality of corn grits; and, (iv) High power requirement that resulted to high operating cost per kilogram output. The above problems are all associated to the design of dehuller-degerminator.

B. Presence of tip caps in the corn grits

During the conduct of field interview, it was discovered that the major part of the corn kernel that causes irritation when cooked corn grits are served in the table is primarily the presence of tip cap and not totally the hull. During laboratory trials, the process of washing corn grits before cooking can separate the hull from the endosperm. Given the almost similar size and bulk density of tip cap with corn grits with sizes of 0.86mm to 2.0mm, separating these two particles is still plausible but the utilization of sifter and aspirator are no longer applicable.

The tip cap is the attachment point of the corn kernel to the cob, through which water and nutrients flow – and is the only area of the corn kernel not covered by the pericarp. The germ, hull and tip cap account for approximately 10, 5 and 1% of corn kernel dry weight, respectively [2].

As such, the tip cap should be separated during degerminationprocess while the sizes of degerminated corn kernels are significantly bigger than the tip cap.Degerminated corn kernels are the main product after degermination process. Graded corn grits product is achieved after the corn kernels have passed through the dehulling-degermination, milling, and grading processes.

C. Features of the new design

Fig. 1shows the different parts and components of the dehuller-degerminator assembly as follows: corn kernels input hopper, feeding control device, inlet duct, inlet duct sleeve, degermination chamber, dented hexagonal screen huller, feeding auger and counter flow auger that are both mounted to a horizontal shaft, discharge gate, outlet duct, outlet chute, and the prime-mover.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

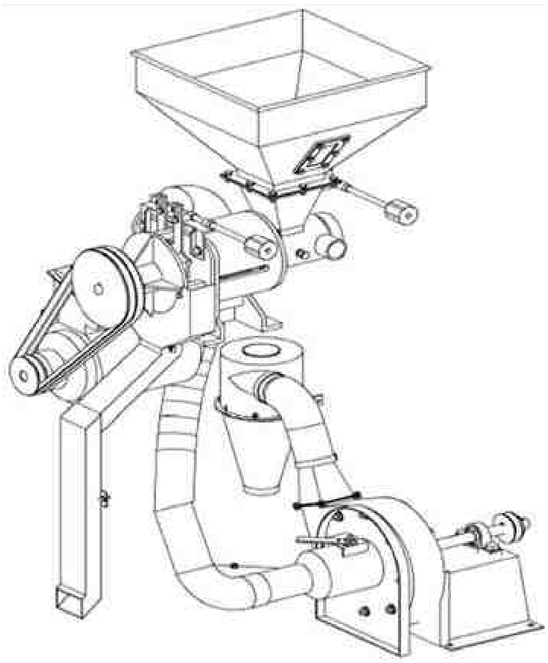

Figure1. Isometric View of the Dehuller-degerminator

The final design of the dehuller-degerminator has an input capacity of 300-350kg/h. The optimum capacity was primarily based on the load capacity of a 5-hp electric motor, single-phase, 220V at 60Hz. An electric motor was strictly preferred than an engine to address the problem of starting a dehuller-degerminator. A single-phase electric motor was used to ensure that the machine can be easily installed in the rural or remote areas. The electric line commonly available in the rural areas is single-phase, 220V at 60Hz. A three-phase electric line is seldom available in the countryside.

It is noteworthy to mention that during the onset of designing the dehuller-degerminator, the process of conditioning or steeping corn kernels before passing through the degermination process was fully considered as part of the dry-milling process[10], [11]. Conditioning is the rewetting of dried corn kernels to about 18% to 22% moisture content and tempering it to make the pericarp and the germ more pliable and easier to remove [3].After several laboratory test trials were conducted, however, such initial plan was abandoned due to the following observations: (i) frequent clogging of wet corn kernels inside the degermination chamber during operation; (ii) non-suitability of infested corn kernels to steeping due the deep penetration of water to the endosperm instead of the original purpose of steeping only the hull and germ of the corn kernel to facilitate its removal from the endosperm; and, (iii) the susceptibility to corrosions of steel materials used in the fabrication of the dehuller-degerminator due to its frequent exposure to moisture.

D. Process of degermination under the new design

As designed, corn kernels are loaded to the input hopper. When the feeding control device is opened, corn kernels start to fall to the inlet duct, wherein the flow of corn kernels can be regulated by the feeding control device. Corn kernels then enter the dented hexagonal screen huller through the aid of the feeding auger, wherein its shaft is connected to an electric motor. As the counter flow auger rotates, the clearance between the counter flow auger and the dented hexagonal screen huller is constantly changing, causing corn kernels to experience alternate periods of compression and relaxation. This produces efficient rubbing of corn grains with each other. Likewise, as the corn kernels move across the dented hexagonal screen huller, it simultaneously tears the tip cap and germ and simultaneously peels the hull of the corn kernels. The application of force and friction creates rubbing and abrasive actions that separates the bran, germ, and tip cap from the endosperm. A suction blower with a cyclone, both connected to the degermination chamber extracts the bran, germ, and tip cap outside the dented hexagonal screen huller. A discharge gate is installed at the tail-end of the dented hexagonal screen huller to regulate the degree of degerminationof corn kernels. From the degermination chamber, degerminated corn kernels then proceed to the outlet duct and finally to the outlet chute

E. Performance of the developed dehuller-degerminator

During laboratory testing, the performances of each component were fully observed and several modifications were undertaken until the desired outputs were achieved.

In the initial design, emery stone was used to degerminate corn kernels. The emery stone was manufactured using eight pieces of grinding stone with 4 inches diameter, 1 inch thick and 1 inch bore (coarse number 36) and bind with steel epoxy. The utilization of several pieces of grinding stone was initially pursued in order to replace only the dented or damaged part of the emery stone, without necessarily replacing the whole component of the emery stone, to reduce the cost of maintenance.

However, after the field testing, wherein a total of 1,228 kg of corn grains were milled, the Emery Stones were partly torn. In line with this, the dehuller-degerminator assembly was redesigned using a more durable material, a heat treated carbon steel hexagonal dented screen huller, as its abrasive mechanism with counter flow auger.

The technical performance of the Dented Screen Huller was tested and compared with the Emery Stone in the laboratory using a small scale model with input capacity of 200-250kg/h. As shown in Table2, the performance of Dented Screen Huller was significantly more superior to the Emery Stone in terms of milling capacity and output capacity. While the Emery Stone can produce higher input capacity of 257.6kg/h than that of Dented Screen Huller at 201.7kg/h, the latter can provide higher output capacity of

TABLE II. Performance of Cornmill using Different Types of Dehuller-Degerminator Mechanisms

Performance Parameters	Emery Stone	Dented Screen Huller
Input Cap. (kg/h)	257.6[a]	201.7[a]
Output Cap. (kg/h)	85.5[a]	149.3[c]
Milling Rec. (%)	71.3[a]	80.0[a]
Milling Cap. (kg/h)	119.9[a]	181.7[c]
Degerminator Eff. (%)	91.5[a]	94.7[a]

Note:Means having the same super scripts are not significantly different at 5% level.

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication Pvt. Ltd.

149.3kg/h than the former without comprising the quality of corn grits. Given the much superior performance of the Dented Screen Huller than the Emery Stone, the former was used in the final design.

In order to optimize the operation of the dehuller-degerminator, the rotating auger which is powered by a 5-hp electric, single-phase, was subjected to different shaft speed. Table3 shows that at the set speed of 1,250 rpm for the rotating auger, the corn mill could reach its maximum milling capacity of 367.0 kg/h without breaking the electric motor given a dominant electrical load reading of only 16 amperes. Likewise, at this speed, the dehuller-degerminator can achieve a highest output capacity of 308.7 kg/h with *main product recovery* of 79.2% and *degerminator efficiency* of 83.8%. As such, the results of the test trials revealed that the most appropriate shaft speed needed for the rotary auger under the current design of the dehuller-degerminator assembly of a corn mill is 1,250 rpm.

TABLE III. PERFORMANCE OF THE DEHULLER-DEGERMINATOR USING DIFFERENT SHAFT SPEED

Performance Parameters	Shaft Speed of the Auger (rpm)			
	600	900	1250	1991
Main Product Recovery (%)	79.3[a]	78.5[a]	79.2[a]	74.9[a]
Degerminator Efficiency (%)	82.8[a]	82.0[b]	83.8[c]	92.5[d]
Input Capacity (kgh^{-1})	324.9[a]	398.9[b]	449.9[c]	481.6[d]
Output Capacity (kgh^{-1})	216.7[a]	270.1[b]	308.7[c]	301.5[d]
Milling Capacity (kgh^{-1})	261.0[a]	324.1[b]	367.0[c]	375.2[d]
Dominant Current Reading (amp)	11.2[a]	15.3[b]	16.0[c]	20.35[d]

Note:Means having the same super scripts are not significantly different at 5% level

F. Efficiency of the dehuller-degerminator to reduce aflatoxin content

The developed dehuller-degerminator was also tested according to its capability to eliminate aflatoxin content of damaged corn kernels.

Table4 shows the level of aflatoxin of corn kernels samples before and after passing through the dehuller-degerminator. Based on the result of the aflatoxin analysis, the corn kernels samples have an initial aflatoxin content of 331.5 ppb. Based on industry standard, such level of aflatoxin contamination is not fit for human and even for animal consumption since the acceptable safe limits are 20 ppb and 50 ppb, respectively[12]. However, once the corn kernels have passed through the newly developed dehuller-degerminator, the aflatoxin content of the degerminated corn kernels was reduced to 28.5 ppb or a reduction of 91.4%. Such finding is consistent with the research of [13]wherein they found out the process of dehulling can decreased aflatoxin levels by up to 70% in corn samples containing 270 ppb aflatoxin levels.

Dehulling corn eliminates the pericarp (hull), underlying aleurone layer, hilum and a sizeable portion of the germ. These fractions are usually the more highly contaminated parts of the grain [10], [14]. Aflatoxigenic molds easily invade the hilum because of the hygroscopic nature of the tip cap. Similarly, the germ is prone to heavy mold infestation due to its hydrophobic nature, which permits a high water activity even when the overall moisture content of the grain is low. The soft texture of the germ also enables easy penetration of fungal mycelia into the germ as compared to the endosperm and thus fungal growth and aflatoxin production is significantly higher in the germ than in other kernel tissues [15], [16].

TABLE IV. Aflatoxin Level Of Corn Kernels Samples And Its Product And By-Products

	Trial 1	Trial 2	Average
Corn Grain	334	329	331.5
Degerminated Corn kernels[1/]	21	24	22.5
By-Product[1/] (Hull, Germ, Tip Cap)	136	133	134.5

1/ After subjected to degermination process

IV. CONCLUSION

Because of the inefficiency of available village-type corn mills in the Philippines, it is imperative to develop a new type of dehuller-degerminatorof the corn mill to satisfy the technical specifications prescribed in the Philippine Agricultural Engineering Standard.

The innovative design of the newly developed dehuller-degerminator features a hexagonal dented screen huller with counter flow auger and suction blower to efficiency separate the tip cap, germ, and hull from the endosperm. The developed dehuller-degerminator with milling capacity of 367 kg/h provides a high milling recovery of 79.2% and *degerminator efficiency* of 83.8%.

Significant reduction in aflatoxin level of highly infested corn kernels was observed once it passed through the developed dehuller-degerminator. This could help reduce postharvest losses and provide additional corn grits supply to the country.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Bureau of Agricultural Research, Department of Agriculture, Philippines for providing the total fund requirements of this project; and to the officials of the Municipal Agricultural Office in Cataingan, Masbate, Philippines for their full support during the conduct of field testing of the prototype unit in their area.

REFERENCES

1. DA-Corn Program, “White Corn Industry Development Roadmap”, Department of Agriculture, Philippines, 2014.
2. F.R. Earle, J.J. Curtis, and J.E. Hubbard, “Composition of the Component Parts of the Corn Kernel”, Cereal Chemistry, vol. 23, pp.504-511, 1946.
3. AMTEC, “Philippine Agricultural Engineering Standard Specification for Cornmill (PAES 210:2000)”, Agricultural Machinery Testing and Evaluation Center, University of the Philippines at Los Banos, Laguna, Philippines, 2001.

4. A.J. Peplinski, R.A. Anderson, F.B. Alaksiewicz, "Corn Dry-milling Studies: Shortened Mill Flow and Reduced Temper Time and Moisture", Cereal Chemistry,vol. 61, no. 1, pp.60-62, 1984.
5. O.L. Brekke and L.A. Weinecke, "Corn Dry-Milling: A Comparative Evaluation of Commercial Degerminator Samples", Cereal Chemistry, vol. 41, no. 5, pp. 321-328, 1964.
6. AMTEC, "Philippine Agricultural Engineering Standard Method of Test for Corn Mill (PAES 211:2000)", Agricultural Machinery Testing and Evaluation Center, University of the Philippines at Los Banos, Laguna, Philippines, 2001.
7. G. Hassan, and B.B. Llyod, "Aspergillus Flavus and Aspergillus Parasiticus: Aflatoxigenic Fungi of Concern in Foods and Feeds: A Review", Journal of Food Protection, vol. 58, pp. 1395–1404, 1995.
8. J.A. Hall, and P.C. Wild, Epidemiology of Aflatoxins Related Disease, In L. D. Eaton & J. D. Groopman (Eds.), The Toxicology of Aflatoxins, London: Academic Press, Inc., pp. 233–258,1994.
9. L.A. Esteves, N.C. Santiago, E.R. Regpala, B.P. Roderos, A.N.F Bulanadi., and M.A.Acda, "Monitoring and Surveillance of Aflatoxin in Selected Corn Producing Areas", Terminal Report, Philippine Center for Postharvest Development and Mechanization, 2008.
10. O.L. Brekke, E. Griffin, Jr., and P. Brooks, "Dry-Milling of Opaque-2 Corn", Cereal Chemistry, vol. 48, pp. 499-511,1991.
11. A. Peplinski, R. Paulsen and A. Bouzaher, "Physical, Chemical and Dry-Milling Properties of Corn of Varying Density and Breakage Susceptibility", Cereal Chemistry, vol. 69, no. 4, pp. 397-400,1992.
12. DA-BAFS, "Philippine National Standards for Shelled Corn (PNS/BAFS 10:204)", Bureau of Agriculture and Fisheries and Product Standard, Department of Agriculture, Philippines, 2014
13. C. Mutungi, P. Lamuka, S. Arimi, J. Gathumbi, C. Onyango, "The Fate of Aflatoxins During Processing of Maize into Muthokoi – A Traditional Kenyan Food", Food Control, vol. 19, pp. 714-721, 2008.
14. O.L. Brekke, A.F. Peplinski, G.W. Nofsinger, H.F. Conway, A.C. Stringfellow, R.R. Montgomery, et al., "Pilot-plant Dry Milling of Corn Containing Aflatoxin", Cereal Chemistry, vol. 52, pp. 205–211, 1975.
15. R.L. Brown, T.E. Cleveland, G.A. Payne, C.P. Woloshuk, K.W. Campbell, and D.G. White, "Determination of Resistance to Aflatoxin Production in Maize Kernels and Detection of Fungal Colonization Using an Aspergillus Flavus Transformant Expressing Escherichia coli β-glucuronidase", Phytopathology, vol. 85, pp. 983–989,1995.
16. N.P. Keller, R.A.E Butchko, B. Sarr, and T.D. Phillips, "A Visual Pattern of Mycotoxin Production in Maize Kernels by Aspergillus spp.", Phytopathology, vol. 84, pp. 483–488, 1994.

Michael A. Gragasin, is a Supervising Science Research Specialist at the Philippine Center for Postharvest Development and Mechanization (PHilMech), Department of Agriculture, Philippines. Dr. Gragasin led the implementation of projects geared towards achieving food sufficiency in the Philippines.

Dr. Gragasin graduated with a degree of Bachelor of Science in Agricultural Engineering. He was awarded a Mombusho scholarship program and pursued Masteraland Doctoral Degrees in Agricultural Economics at Chiba University, Japan. He also became a post doctorate fellow in Chiba University under the Japanese Government JASSO Program. He published and presented research papers in international journals and conferences in USA, Korea, Japan, Philippines, and Pakistan. In 2013, he was awarded the Most Outstanding National Agricultural Engineer in the Field of Postharvest Technology and Food Engineering by the Philippine Society of Agricultural Engineers.

Romualdo C. Martinez is a Chief Science Research Specialist at the Philippine Center for Postharvest Development and Mechanization (PHilMech), Department of Agriculture, Philippines. He led the conduct of research in the field of agricultural mechanization.

He graduated with a degree of Bachelor of Science in Agricultural Engineering. He was awarded a scholarship programs and pursued Masteral Degree in Engineering Postharvest Technology (Hisamatzu Prize) at the Asian Institute of Technology, Thailand and Doctor of Agricultural Science in Agricultural Engineering at University of Hohenheim, Germany (Magna Cum Laude).

Dr. Martinez is a National Postharvest Consultant at the Food and Agriculture Organization of the United Nations (UN-FAO), Philippines. He is member of the American Society of Agricultural Engineers.