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Potential application of locally grown Sri Lankan corn varieties to utilize in the food industry; Corn Starch and Corn Syrup

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Abstract:

Corn (*Zea mays* L.) is widely used as a raw material in food and feed industry in Sri Lanka. The present study focuses to produce value added products; Corn Starch and Corn Syrups from local corn varieties.

Predominant cultivated varieties of Jet 999, Pacific 984 and Bhadra were analyzed for their proximate composition and results (w/w% on dry basis) were ranged from ash content; 1.85±0.36 - 2.60±0.25, protein content; 7.66±0.20-10.73±0.21, fat content; 1.91±0.07-3.44±0.15, fiber content; 3.05±0.15-3.38±0.07 and carbohydrate content; 80.88-84.63% respectively.

Corn starch was isolated using wet milling process. Starch yield to corn seeds (w/w% on dry basis) of Jet 999, Pacific 984 and Badra were 18.84±3.37, 13.23±0.74 and 0.80±0.21 respectively. Since starch yield of Bradra was very low, further studies were not continued. Proximate composition of isolated corn starch from Jet 999 had ash, protein, fat, fiber, and carbohydrate content (w/w% on dry basis) of 1.63±0.03, 3.45±0.12, 1.36±0.03, 1.70±0.05 and 91.79 whereas Pacific 984 had 1.73±0.15, 2.42±0.09, 1.16±0.32, 1.70±0.14 and 93.40 respectively (similarly commercial corn starch had those contents of 0.07±0.05, 0.74±0.04, 0.47±0.13, 0.30±0.07 and 92.14 respectively). Isolated corn starch from Jet 999 contained 77.64±2.85% of starch and 1.06±0.05% of acid insoluble ash whereas Pacific 984 had 42.50±0.30% and 1.34±0.01% respectively (similarly commercial corn starch had those values of 84.85±1.12%, and 0.13±0.05% respectively).

The corn syrup produced from Jet 999 had pH 4.32, ^{o}Brix value 75 and Dextrose Equivalent (DE) 67.80 whereas Pacific 984 had pH 4.49, ^{o}Brix value 76, and DE 72.8. Present study showed that Jet 999 as a promising variety for corn starch and syrup industry.

Key words: Corn – Cornstarch - Corn syrup - Corn Industry - Wet milling

Introduction:

Corn (*Zea mays* L.) is one of the most important coarse grains in Sri Lanka for which around 30,000 ha of second largest extend of land area next to rice is devoted annually for cultivation [1]. Presently, corn varieties for cultivation are recommended by Department of Agriculture and they are both locally developed varieties and common hybrid corn varieties such as Pacific 984, Jet 999 (NK 7328), Pacific 999, NK 40 (jumbo) and NK 48 (Rambo).

Corn is widely used for human consumption as well as animal feed production. In 2012, it was recorded the highest corn production in Sri Lanka and hereafter it began to export to other countries [2]. Export data revealed that 4229 tonnes of corn was exported in 2014[3].

Local consumption is estimated about 33,000 tons for the requirements of complementary foods and other food products. In addition to that corn products such as corn flakes, corn oil, corn starch and corn syrup are imported to the country for different uses. However still reported evidences were not available regarding the production of corn starch and syrup locally [4].

With high local production of corn, it can be comprehensively utilized to produce economical value added corn based products which have high demand for commercial purposes. Therefore country needs to look forward to undertake a maximum advantage of this opportunity to lift up the rapid momentum of development in agricultural and industrial sectors in order to save the annual import expenditure.

Presently, corn starch and corn syrup both are totally imported from other countries. Corn starch has a wide range of food applications such as, thickening agent in liquid-based foods, (e.g. Soup, Custard) and confectionaries [5][6]. Similarly Glucose syrup is a viscous liquid product that is utilized in bulk quantities for many food applications including bakery, confectionery and dairy industries [7].

Presently, government has to spend about 450 million Sri Lankan rupees yearly for importation of corn syrup [8]. Corn starch is widely used to produce glucose product in Western and European countries and some of the Asian and African countries. There are many corn varieties, among them the dent corn is used as the primary source of corn syrup production [9]. Presently, our country doesn't produce this type of corn variety. Therefore, this study is focused on optimizing process and assessing the quality parameters of corn starch and corn syrup using widely grown local corn varieties with intension of identifying the suitable locally available corn varieties for starch production and corn syrup production.

Materials and Methods:

Materials

Corn seeds

Commonly cultivated corn varieties were selected according to the Statistical Data obtained from Hector Kobbakkaduwa Agrarian Research Station at Colombo 07 and corn seeds were collected from CIC farms in Dambulla (Jet 999), Prima Company (Pacific 984) and Mahailluppallama Field Crop Research and Development Institute (Bhadra).

Enzymes

Starch hydrolysis enzymes of Liquozyme® SC (thermostable alpha amylase E.C. No. 232-565-6) and Saczyme® (glucoamylase E.C. No. 232-877-2) were purchased from Novozymes A/S, Denmark.

Methods

Preparation of corn seed powder

Corn seeds were kept in the dryer (Model: Pratchitt) at 50^{o}C about 6 h to reduce the moisture content. Seeds were ground to 4 mm sieve size using centrifugal mill (Model: Retsch).

Isolation of corn starch

Five hundred gram (500 g) of corn seeds from each variety were measured in 2 repetitions and 800 ml of water was added with 2% Sodium Meta-bisulphite into a container. Samples were then soaked approximately 48 h. After 48 h, samples were ground using wet milling grinder (Model: Sawa boy) and solution was collected to a container. The hull was removed by using 4mm rotary wire mesh sieve and filtered solution was re-filtered using 250 µm wire-mesh sieve. After sieving through 250µm sieve, the residues were re-milled, using wet milling grinder (Model: Sawa boy) and filtered. The combined filtration was centrifuged at 4700 rpm for 20 minutes using a centrifuge (Model- Sigma 3-18k). White coloured lower layer of starch and yellow coloured upper layer of gluten were separately dried in a domestic dehydrator (Model: American Harvest) at 60^{o}C, packed in polypropylene bags and kept for further analysis.

Compositional analysis

Corn seeds of varieties of Jet 999, Pacific 984, Bhadra and commercial sample (mixed varieties) were analyzed for their proximate composition and results were compared with the composition of commercial corn seeds by following the respective protocols as described in AOAC, 2012[10].

Moisture content of the corn seed flours was determined according to the oven drying method as described in AOAC, 2012- 925.09B, applying gravimetric principal. The crude protein content of the legume seed flour was determined by kjeldahl method as specified in AOAC, 2012-920.87 using Kjeldahl heating digestion unit (VELP Scientifica DK 20) and Kjeldahl semi distillation unit (VELP Scientifica DK 139). The crude fat content was determined by soxhlet extraction method according to AOAC, 2012- 920.39C using automatic extraction systems Soxtherm (C. GERHARDT GMBH & CO. KG • Analytical Systems). Crude fibre content was determined according to the method as described in AOAC, 2012-962.09E using Fibertec™ M-6 Fibre Analysis System (FOSS-1020 HOT EXTRACTOR). Ash content was determined by dry ashing method followed by gravimetric principal as described in AOAC, 2012-923.03 using muffle furnace (Model: Lenton). Total carbohydrate content was determined according to the method described by Sompong using calculation method [11].

Chemical analysis of isolated corn starch

Proximate composition analysis

White coloured isolated corn starch from each variety separately analyzed for the proximate composition of fat, protein, fibre, ash and moisture AOAC, 2012 [10] and carbohydrates from by difference method.

Quality evaluation of isolated starch

Acid insoluble ash

Acid insoluble ash content in isolated corn starch was determined as method described in SLS -1992 [12].
Isolated corn starch sample (2.0000g) was measured in to a previously cleaned, dried weighed porcelain crucible and it was placed in furnace at 550^{o}C for 5 h. Weight of the sample with crucible was measured after incineration. 5M HCl (25ml) was added in to the crucible and it was covered with watch glass and placed in a water bath for 10 minutes.
Cooled solution was filtered through ashless filter paper and washed with distilled water to get residue free from acid. Filter paper with residuals was placed in an oven for 30 minutes. After the sample was ignited in a furnace at 550^{o}C for 5 h, content was weighed and calculated the acid insoluble ash.

Determination of starch content

Starch content in isolated corn starch was determined as method described in SLS-1992 [12].
Defatted flour sample of isolated corn starch sample (2.0000 g) was weighed into a previously cleaned, dried round bot-

tom flask. 200 ml ethanol/distilled water (80:20) solution was added in to the round bottom flask, fixed to soxhlet apparatus and refluxed for 2 h. The contents were filtered through whatman No.1 filter paper and remained solid flour was washed with distilled water in two times. The residue was added in to a round bottom flask and 2M HCl 100 ml was added followed by refluxing for 2 h. pH of the solution was adjusted to pH 7 by adding Na_2CO_3 solution and volume was made upto 250 mL. Titration was performed using 10 ml of mixed Fehling's A and Fehling's B solutions against starch solution in the presence of methylene blue indicator till colour change was become to brick red.

Starch content of the isolated starch was determined using following equation.

Starch content = 0.90x Dextrose

Production of corn syrup at laboratory scale

Isolated corn starch (on dry weight basis) was mixed with distilled water at 1:10 ratios to make final resultant slurry containing 10% sediments. The prepared slurry was treated with α – amylase at concentration of 0.03 (% v/w) and slurry was heated for 1 h at 95-100°C temperature range. The slurry temperature was maintained using a water bath with continuous stirring. The liquefied slurry was subjected to saccharification. It was cooled to room temperature and pH of the medium was adjusted to 4.5 using citric acid as pH 4.5 is the optimum pH for the glucoamylase enzyme. The slurry was saccharified with glucoamylase enzyme at concentration of 0.03 (% v/w) at 60°C for 3 h with continuous heating and agitation using a magnetic stirrer. The sample was cooled and centrifuged to 10000 rpm for 20 minutes. Sample was filtered through filter paper (No: 04) and concentrated using Rotar-evaporator (Buchi B-480) until °Brix value gained over 70%.

Reducing sugar contents were measured using 3,5-di-nitro-salicylic acid (DNS) colorimetric method [13][14] and DE values were calculated according to following equation.

$$DE = \frac{\text{Reducing sugars expressed as glucose (g)}}{\text{Total soluble solids (g)}} \times 100$$

Results and Discussion:

Proximate composition of corn seeds from local varieties of corn

Predominant cultivated corn varieties of Jet 999, Pacific 984, Bhadra and commercial corn seeds found in local markets were analyzed for the proximate composition and results are presented in Table 1.

Table I: Proximate composition of corn seeds in varieties of Jet 999, Pacific 984, Bhadra and commercial seeds

Nutritional parameters	Commercial	Jet 999	Pacific 984	Bhadra
Energy(kcal)	394.18	397.4	391.40	388.47
Moisture	10.0±0.34	9.44±0.46	9.74±0.25	8.78±0.36
Ash	1.94±0.20^b	1.85±0.36^c	2.60±0.25^a	1.89±0.12^c
Protein	9.45±0.19^b	10.73±0.21^a	7.66±0.20^d	8.19±0.18^c
Fibre	2.32±0.08^c	3.10±0.03^b	3.05±0.15^b	3.38±0.07^a
Fat	2.26±0.18^b	3.44±0.15^a	2.80±0.03^b	1.91±0.07^c
Carbohydrates	84.01	80.88	83.89	84.63

Results were expressed in Mean ± Standard Deviation of triplicates (%w/w on dry weight basis).
Means with same superscript in a row were not significantly different ($p > 0.05$)
* Standard deviations were not applicable for values of carbohydrate since they were obtained by subtracting sum of average values of other nutrients from 100%

The initial moisture content of corn seeds was 9.44%, 9.74%, 8.78% and 10.0% in Jet 999, Pacific 984, Bhadra and commercial respectively. Ash content of all three varieties analyzed was varied from 1.85±0.36 - 2.60±0.25 on dry weigh basis indicating Pacific 984 variety had the significantly highest ash content. Sule et al., 2014 [15] reported that ash content of corn ranged from 1.10-2.95% at moisture content ranged from 11.6-20.0% where as Cortez and Wild-Altamirano, 1972 [16] reported that 1.2-2.9% of ash content contained in different corn varieties in Gutemala at moisture content of 9.5-12.3%. Juliano et al., 2003 [17] reported that the crude ash content of corn was 1.4% at moisture content of 14%. Similar results were obtained from the present study for ash content.

The values for protein contents on dry weight basis in corn seeds were significantly different ($p \leq 0.05$) from each other and the highest amount was obtained Jet 999 (10.73±0.21%) followed by commercial corn seeds (9.45±0.19%), Bhadra (8.19±0.18) and Pacific 984 (7.66±0.20). Similar findings were observed by other scientist but with slight variations. Sule et al., 2014 [15] reported 4.5-9.87% protein content for corn at moisture content ranged from 11.6-20.0%. Cortez and Wild-Altamirano, 1972 [16] reported 5.8-13.7% of protein content in different corn varieties in Gutemala at moisture content of 9.5-12.3%. Juliano et al., 2003 [17] reported that the crude protein content of corn at moisture content of 14% was 9.8%. According to the previous data for protein content our corn varieties are in agreement of those results.

The crude fibre contents of all three varieties were ranged from 3.05±0.15 ±3.38±0.07 % indicating Bhadra variety had significant highest fibre content

Sule et al., 2014 [15] reported that 2.10- 26.70% of fibre content contained in the seeds with moisture content ranged from 11.6-20.0%. Cortez and Wild-Altamirano, 1972 [16] reported 0.8-2.9% of fibre content were present in different corn varieties in Gutemala (at moisture content ranged 9.5-12.3%). According to the above data for fibre content our corn varieties are in agreement with Cortez and Wild-Altamirano [16].

Fat content of the varieties were ranged from 1.91±0.07-3.44±0.15 showing the highest fat content in Jet 999. Sule et al., 2014 [15] reported 2.17-4.43% fat content for corn at moisture content ranged from 11.6-20.0% while Cortez and Wild-Altamirano, 1972 [16] reported 2.2-5.7 % of fat content in different corn varieties in Gutemala (at moisture content ranged 9.5-12.3%). Juliano et al., 2003 [17] reported that the crude fat content of corn at moisture content of 14% was 4.9%. It is seen that our results are in the range of previous studies.

The major chemical composition of corn kernal is carbohydrates which consist of starch and simple sugars. In the present study corn kernel contained 80.88-84.63% (on dry weight basis) of carbohydrates. Sule et al., 2014 [15] reported 44.60-70.0% carbohydrate content for corn at moisture content ranged from 11.6-20.0% while Cortez and Wild-Altamirano, 1972 [16] reported 66.0-75.9 % of carbohydrate content in different corn varieties in Gutemala (at moisture content ranged 9.5-12.3%). Juliano et al., 2003 [17] reported that the available carbohydrate content of corn at moisture content of 14% was 60.9%. According data observed, it is seen that current data are already in agreement with previous studies.

Isolation of starch and gluten

Starch extraction was performed by soaking kernels in water containing small amount of Sodium Metabisulphite for 24-48 h. Soaking softens the corn kernels for grinding, facilitates disintegration of the protein matrix that encapsulates the starch granules in the endosperm and removes solubles, mainly from the germ to increase germ recovery [18]. The Sodium Metabisulphite helps to prevent the fermentation process and also helps to separate starch and protein. After soaking, wet grinding was performed in a wet milling grinder and resultant slurry containing parts of the kernel, including hull, gluten and starch components were sent through number of sieving meshes while the hull particles were removed by screening. The resultant filtration containing gluten and starch is separated by centrifugation in bucket centrifuge (Model- Sigma 3-18k). The lower white coloured starch layer was separated from upper yellow coloured gluten layer. Both these separated layers were dried in a domestic air dryer to bring down moisture content. Isolated starch was compared with commercial corn starch (Market brand; Edingbero) and those layers were analyzed for the proximate composition and results are presented in Table 2 and Table 3.

Table 2 Composition analysis of isolated starch

Chemical parameters	Commercial	Jet 999	Pacific 984
Yield* (% w/w)	NA	18.84±3.37	13.23±0.74
Moisture	6.0±0.50	13.10±0.71	11.34±0.65
Protein	0.74±0.04	3.45±0.12	2.42±0.09
Fibre	0.30±0.05	1.70±0.05	1.70±0.14
Fat	0.47 ±0.32	1.36±0.03	1.16±0.32
Ash	0.07±0.05	1.63±0.03	1.73±0.15
Acid insoluble ash	0.07±0.01	1.06 ±0.05	1.34±0.10
Carbohydrates	92.14	91.79	93.40
Starch	84.85±1.12	77.64±2.85	42.50±0.30

NA-Not Available

Results were expressed in Mean ± Standard Deviation of triplicates (%w/w on dry weight basis).

* Yield was expressed as extracted starch to initial raw material of corn seeds (%w/w on dry basis)

In industrial starch extraction processes, starch and protein were separated by batch centrifugation process due to the greater average density of starch granules (1.5 g/cm3) than the density of the protein particles (1.1 g/cm3) in the slurry [19]. After centrifugation, separated starch and protein layers were decanted, and the protein layer, which lay above the starch, was scraped off. More water is added to the partially cleaned starch, and the centrifuging, decanting, and scraping cycle is repeated until starch of desirable quality is obtained [20]. Wet-milling facilitates for removal of fibrous material derived from the pericarp and endosperm cell walls by using sieve shaker screens.

In laboratory scale trial, the extractable starch yield which is defined as the extracted starch content to the initial raw material of corn seeds on dry weight basis were 18.84%, 13.23% and 0.80±0.21% for Jet 999, Pacific 984 and Bhadra respectively. Since the extracted starch yield of Bhadra was very low further studies were not carried out with Bhadra variety.

According to the results, the highest starch yield was obtained for Jet 999. Therefore the best variety for obtaining corn starch is jet 999. This variety can be used for the production of corn starch at commercial scale. Wehling et al., 1993 [21] reported that starch yield of corn seed is dependent on corn variety which is generally ranged from 47.2% to 64.5%. Yellow dent corn hybrids grown in United States contained high value of 65–70% of starch on dry weight basis [22]. Fox et al., 1992 [23] reported similar results, but the starch yields of present studied varieties were lower than the above mentioned values. This variation could be achieved mainly due to the variation among the varieties and processing techniques used for the extraction of corn starch. Generally, laboratory scale trials produce lower starch yields than industrial scale trials. It is mainly due to the industrial methods are capable of extracting starch more effectively with modern type of efficient equipments than the simple physical laboratory methods. Further amount of starch extracted depends basically besides on the method used, the harvesting time of the corn and time taken to reach the processing from the harvesting.

Moisture contents in the isolated starch from corn varieties were higher than the commercial corn starch. It is mainly due to the, in the present study domestic air drying technique was used for drying whereas in the commercially efficient vacuum air drying techniques are used.

In the present study, the contents of protein, fibre, fat, ash and acid insoluble ash contents in isolated starch of corn varieties of Jet 999 and Pacific 984 were higher than the commercial corn starch (Table 2). It is seen that the starch was not fully separated in the present study and also it contained with other residual components. The percentage remaining residual levels were high in isolated starch due to the problems encountered in laboratory trial. It may be due the speed of centrifuge was not met to the separation in to clear layers.

The starch content of isolated starch from Jet 994 and Pacific 984 were 77.64±2.85% and 42.50± ±0.30% respectively and values were lower than the commercial corn starch. It is seen that the Pacific 984 had less starch content and high content of other components including more dietary fibre and other soluble carbohydrates.

Acid insoluble ash content of commercially available flour, jet 999 and pacific 984 were 0.76±0.07% 1.06±0.05% and 1.34±0.10% respectively. Acid insoluble ash consists primarily of silica and silicates. According to the results pacific 984 had high acid insoluble content (1.34±0.10%) than jet 999 (1.06±0.05%) and commercially available corn flour (0.76±0.07%).

The yellow coloured upper gluten layer was dried in domestic air dyer (Model: American Harvest) to reduce moisture content approximately 6.0% and quality evaluation of layer was carried out. This upper gluten layer contained higher amount of protein content that isolated starch layer as shown in Table 2.

Table 3 Quality evaluation of isolated gluten layer

Chemical parameters	Jet 999	Pacific 984
Yield*	10.52±0.67	6.35±0.35
Moisture	6.87±0.47	6.49±0.43
Ash	0.55±0.03	0.45±0.05
Protein	8.03±0.3	7.59±0.15
Acid insoluble ash	0.06±0.01	0.07±0.01

Results were expressed in Mean ± Standard Deviation of triplicates (%w/w on dry weight basis).
*Yield was expressed as isolated gluten content to the initial raw material of corn seeds on dry weight basis

Quality evaluation of corn syrup from corn varieties of Jet 999 and Pacific 984

Corn syrup was produced by using isolated starch from Jet 999 and Pacific 984 according to the method described in methodology section. Physico-chemical parameters of %yield, pH, DE and clarity of glucose syrup from above varieties were carried out and compared with market glucose syrup.

Corn syrup from laboratory scale trial and the market sample were evaluated and results were presented in Table 4.

Table 4 Evaluation of physico-chemical parameters of corn syrup from varieties of Jet 999 and Pacific 984

Parameter	Commercial Glucose syrup	Jet 999	Pacific 984
Yield*	NA	38.2%	33.76%
pH	4.5 ± 0.0	4.32	4.49
^{o}Brix	75	75	76
DE	66.1 ± 1.1	67.8	72.8
Clarity	Transparent/white	Transparent/white	Transparent/white

NA-Not Available
Yield* was expressed as syrup weight to wet starch (% w/w)

According to the Table 4, it is seen that the yield of glucose syrup (% w/w, to wet starch) obtained for Jet 999 (38.2%) was higher than that of Pacific 984 (33.76%). ^{o}Brix value and pH values were shown to be nearly similar values in both syrups. Colour and clarity of the corn syrup from both varieties were white in colour and transparent.

Conclusion:

Considering obtained percentage yields in starch and syrup, present study concluded that Jet 999 is potentially good source for the production of corn starch and corn syrup.

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References:

[1] Department of Agriculture (2006). http://www.agridept.gov.lk. [Online]. Accessed 02 May 2015.
[2]Department of Agriculture (2012). http://www.agridept.gov.lk/index.php/en/crop-recommendations/1026 [Online]. Accessed 05 May 2015.

[3] Sri Lanka Export Developing Board (2014). Sri Lanka Export Statistics, Information Technology Division, Sri Lanka Export Developing Board.

[4]Department of Agriculture (2013). Agstat.Pocket Book of Agricultural Statistics, Department of Agriculture, Sri Lanka, 10, pp. 21-23.

[5]Hegenbart S. (2014). http://www.food productdesign.com/articles/1996/01/understanding-starch-functionality . aspx [Online] Accessed 2 May. 2015.

[6]International starch Institute, (2012). http://www.starch.dk/isi/glucose/tmgluc.asp [Online] Accessed on 5 June 2015,

[7]Rothwell J. (1981). Microbiology of ice cream and related products. In: R.K. Robinson eds., Dairy microbiology; the microbiology of milk products, vol 2, Applied Science Publishers, London and New Jersey, pp 45.

[8]Customs, S.L. (2011). http://www.customs.gov.lk. [Online] Available at: http://www.customs.gov.lk/statistics.html, Accessed 03 May 2014.

[9]Cavette, C. (2014). http://www.madehow.com. [Online] Available at: ,http:// www. Madehow .com/Volume-4/Corn-Syrup, Accessed 05 May 2104.

[10]Official Methods of Analysis of AOAC INTERNATIONAL (2012). 18th ed. USA: Gaithersburg, Md.

[11]Sompong, R., Siebenhandl-Ehn, S., Linsberger-Martin, G. and Berghofer, E. (2011). Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China and Sri Lanka. Food Chemistry, 124 (1), pp.132-140.

[12]Sri Lanka Standards Institute (1992). Specification for corn flour (maize starch). Sri Lanka Standard Institute.

[13] Miller, G. L. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugar, Analytical chemistry, **31**, pp 426-428.

[14] Saqib A.A.N. & Whitney P.J. (2011), “Differential behavior of the dinitrosalicylic acid (DNS) Reagent towards mono- and di-saccharide sugars”, Biomas and bioenergy, **35**, pp. 4748-4750.

[15]Sule Enyisi, I., Umoh V.J., Whong, C.M.Z., Abdullahi I.O., and Alabi, O. (2014). Chemical and nutritional value of maize and maize products obtained from selected markets in Kaduna State, Nigeria. African Journal of Food Science and Technology (ISSN: 2141-5455) Vol. 5 (4) pp. 100-104.

[16]Cortez, A. and Wild-Altamirano, C. (1972). Contributions to the limetreated corn flour technology. In R. Bressani, J.E. Braham & M. Behar, eds. Nutritional improvement of maize. INCAP Pub. L4, Guatemala, INCAP, pp. 99-106.

[17]Juliano B. O. (2003). Structure and gross composition of the rice grain. In: B. O. Juliano eds. Rice Chemistry and Quality. Philippine Rice Research Institute, Philippines, pp. 34-35.

[18]Singh, N. and Eckhoff S. R. (1996). Wet Milling of Corn-A Review of Laboratory-Scale and Pilot Plant-Scale Procedures. Cereal Chem. 73(6), pp 659-667.

[19]Biss, R., and Cogan N, U. (1988). The significance of insoluble protein solubilization in corn steeping. Cereal Chem. 65, pp 281-284.

[20]Finley, J.W., (1993). Poteine removal from Gluten-Starch wash water. western regional research laboratory. Cereal Chemistry, 54(1), pp.131-38.

[21]Wehling, R.L., Jackson, D.S., Hooper, D.G. and Ghaedian, A.R., (1993). Prediction of wet milling starch yield from corn by near infre-red spectroscopy. Cereal Chemistry, 70(06), pp.720-23.

[22]Rooney, L. W., McDonough, C. M. and Waniska, R. D.(2004). The corn kernel. In: C. W. Smith, J. Betran, and E. C. A. Runge, eds. Corn: Origin, History, Technology, and Production. John Wiley and Sons, pp 273-303.

[23]Fox, S. R., Johnson, L. A., Hurburgh, JR., C. R., Dorseyredding, C., and Bailey, T. B. (1992). Relations of grain proximate composition and physical properties to wet-milling characteristics of maize. Cereal Chem. 69, pp 191-197.