Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLVII
Broj 1, 2022.
Strane: 43 – 55

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLVII
No. 1, 2022.
pp: 43 – 55

UDK: 664.78.01:631.21

Original scientific paper
Originalni naučni rad
doi: 10.5937/PoljTeh2201053B

DEVELOPMENT AND PERFORMANCE EVALUATION OF INTEGRATED MILLING-SIEVING-DEWATERING MACHINE FOR GRAIN SLURRY STARCH PRODUCTION

Bethrand Nduka Nwankwojike*[1], Osinachi Stanley Onwuka[1], Onyekachi Marcel Egwuagu[2], Princwil Chibuike Emeh[1]

[1]Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria
[2]Department of Mechanical and Production Engineering, Enugu State University of Science and Technology, Enugu, Nigera

Abstract: This study involves development and integration of a rotary vacuum drum filter to an existing milling and sieving machine to enable full mechanized/continuous milling, sieving, dewatering and water recycling operation in slurry starch production from cereal grains. The resulting milling-sieving-dewatering machine consists of a water dispenser, burr mill, screw press-sieve, rotary drum, 0.5hp 65 kPa vacuum pump and 4.5 HP electric motor as major components that were sequentially assembled to enable flow of material by gravity. This integrated machine operates with an average throughput and extraction efficiency of 70.44 kg/hr and 98.48% respectively while 31.52% constitutes the average moisture content of slurry starch cake processed with it. The innovation induced over 5.39 hours saving and 10% reduction in moisture content of the slurry starch while retaining less than 2% food loss associated with its seed machine. Thereby improving the shelf life/storage potential and mobility of the processed grain slurry starch cake. Water consumption during grain slurry starch production was drastically reduced with this machine because it recycles the water drained after dewatering back to its dispenser for milling and sieving.

*Corresponding Author. E-mail address: jikeobodo@gmail.com

It also reduced drudgery and improved hygiene through elimination of human contact involved in loading/discharging of intermediate processed grain among the three most strenuous and time consuming unit operations in grain slurry starch processing. Therefore, the recommendation of this novel milling-sieving-dewatering machine for effective grain slurry starch production.

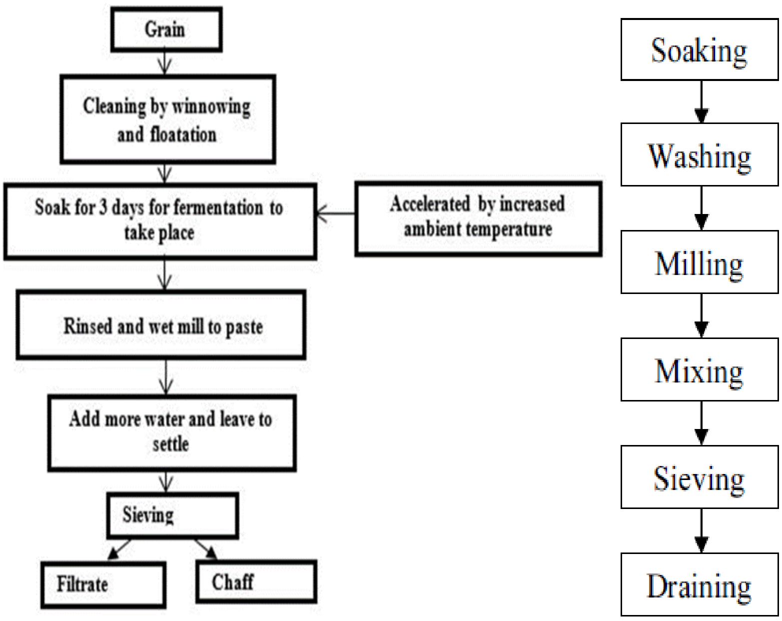
***Key words**: Cereal grain, milling sieving, dewatering, continuous process machine, grain slurry starch, slurry food diets/beverages.*

INTRODUCTION

The search for a full mechanized process/system of extracting slurry starch from cereal grains constitutes one of the outstanding efforts towards attaining food security in most sub-Saharan countries due to high demand for grain slurry food diets/beverages in this region [1, 2]. The high demand for grain slurry based food diets/beverages was attributed to their high nutritive value and fast preparation process [2]. Processing of the dry grains to slurry food diets involves two distinct phases of factory process. The first phase involves sequential grain soaking, milling, sieving and dewatering processes of extracting starch slurry from dry grains while the second phase involves blending of the extracted slurry into different diets or beverages. Soaking process softens the dry hard grains by sopping in water for one to three days depending on the level of fermentation desired to avert stressful milling, which in turn crushes the grains into paste as they mix with water. The sieving involved stirring of the paste on a chiffon cloth tied firmly over a bowl with regulated addition of water to discharge the starch filtrate into the bowl while leaving the residual chaff on the chiffon. Dewatering involves allowing the filtrate to settle into two layers of food slurry at the bottom and a less dense supernatant water at the top before decanting, bagging and pressing of the food slurry to drain its excess water content in accordance with users' desires [1]. Although, the soaking, milling and blending processes usually fit existing/emerging food processing machineries and devices, [1] showed unsuccessful mechanization of sieving and dewatering as bottle neck in this sector. However, the work of [3] which most recent mechanized slurry food processing system were based on never recognized dewatering as unit operation in this sector. This is why the works of [4-8] featured only milling and sieving process integration to eliminate drudgery and human contact with the food materials associated with batch process/standalone systems for slurry starch production. Thereby, leaving dewatering as the only distinct process without adequate attention for mechanization in this sub-Saharan food processing sector.

An '*ogi*" processing plant developed by [4] constitutes an assembly of the multi-stage grinder and the vibration sieving machine while the mill with sieving device of [5] has a mill with curved teeth plates mounted around the grinding chamber, sieve made of a wire-knitted screen and tube that runs into the grinding chamber. Although, the "*ogi*" processing plant and mill-sieving device fostered continuous production in this sector, their extraction efficiency depends on the output of their milling units and volume of water used. The high rate of water consumption and food loss associated with these systems steered the works of [6-8].

The sieving operations was successfully mechanized and integrated to a bur mill by [8] such that the flow of water from the dispenser to the hopper, soaked grain/water matrix from its hopper to the mill and the milled paste to the sieve is continuous and gravity driven. This latest milling and sieving machine of [8] for grain slurry starch production grinds soaked grains and separates its slurry starch from the fibrous chaff content in one flow process with average extraction efficiency of 98.48% amounting to less than 2% slurry food loss to chaff. Its screw- press based sieving unit which extract the slurry starch by compression process aids the release of food materials from grain particles that were not properly crushed during the milling. Another unique feature of this system is that it does not require adding of water to the milled grain paste but uses the water content of the paste for the sieving operation. These innovations obviously raised quest for identification and mechanization of other distinct manual operations in grain slurry starch production. Although, [1] indicated mixing and draining (dewatering) as additional distinct unit operations apart from the ones in [3] as compared in Fig.1., assessment of existing manual and mechanized grain slurry processing systems confirmed dewatering as the only non-mechanized process because mixing or stirring is one of the activities in sieving.



.

Fig.1. Unit Operations' sequence in grain slurry processing
as described by [3] and [1] respectively

The report of [1] revealed that sedimentation and draining activities in gran slurry dewatering process takes not less than 0.04 and 0.05 hr/kg respectively depending on the water content desired also raise concern for mechanization of dewatering process in order to reduce this excessive time lag and drudgery before now.

Hence, the urgent need for a spontaneous dewatering system that can be integrated to the milling and sieving machine to enable continuous milling-sieving-dewatering process in this sector. The desire for flow process system for phase separation of this nature usually lend itself to mechanical centrifugal filtration systems [9, 10]. Centrifugation as a separation process relies on centrifugal force action to separate particles in a solid–liquid mixture into two distinct phases consisting of the sediment and centrifugate/supernatant liquid [10]. Mechanical centrifuge separates mixture by spinning it at high speed within its container to create a centrifugal force which causes radially movement of the dense solid particles away from the axis of rotation to outside of the vessel while the supernatant moves to its center [10, 11]. This centrifuge was further described by [11] as a spontaneous and continuous process separation device because it causes solid to settle more rapidly and completely in a solid in liquids than plate filters. Effective applications of continuous centrifugal filters for dewatering of crystalline solids in the food industry for milk, cheese, edible oil, pulp control in juices, starch and yeast production are very evident in the works of [11-14]. Hence, this study involves full mechanization of milling, sieving, dewatering and water recycling operations in grain slurry food processing by developing and integrating a rotary vacuum drum filter to a slurry food milling and sieving machine.

MATERIAL AND METHODS

Development of the grain slurry food milling-sieving-dewatering machine involved fabrication of a rotary vacuum drum filter and integrating it to an existing milling and sieving machine developed by [8]. The rotary vacuum drum filter (Fig. 2) is a perforated 500mm long open ends cylinder made from 3mm thick stainless steel sheet metal with diameter of 900mm. The perforations were drilled with diameter of 1mm each and 10mm spacing from one another before covering the drum's screen area with filter cloth (muslin bag). The screen area was made of three distinct circumferential zones/vacuum cells for submerging, drying and discharging connected to the vacuum pump via 10mm diameter pipes and its driving 60 mm stainless steel hollow shafts. The shaft was made one end bearings support with trunnion for vacuuming. The slurry food milling and sieving machine (Fig. 3) is an assembly of water dispenser and 3.5 HP diesel engine which drives it milling and sieving units simultaneously via an intermediate shaft. The filter was incorporated to the slurry food milling and sieving machine such that the same prime mover (electric motor) drives it with the mill and sieve simultaneously via an intermediate shaft/v-belts as shown in fig.4. This modification also involved fabrication and incorporation of two troughs, one to the sieved slurry filtrate discharging chute in which the drum submerges as it spins for deliquoring of the filtrate while the other below the drum filter for collection of the supernatant water drained.

This grain slurry food milling-sieving-dewatering machine processes soaked grain to slurry starch cake and chaff as the dispenser feeds its hopper containing the grains with water at a regular rate. The grain-water matrix flows by gravity into the mill which effects the wet crushing while the resulting grain paste flows into the sieve.

The sieve separates the paste into slurry food filtrate and chaff as its auger press compressively moves the paste from the left end of its barrel to the right under the opposing pressure of its conical stopper. This compression effects the oozing of the food filtrate out of the paste into its chute/collection through the sieve's aluminum net/chiffon nested barrel perforations while the chaff intermittently discharges through the barrel's right end aperture regulated by the backward and return motions of the stopper in tune with the barrel pressure. The water content of this filtrate drains out while its grain slurry crystallizes at the surface of the drum as the drum spins with 30% partially submergence in and out of the trough. The caking/dehydration progresses continuously by vacuuming at this filter's drying and discharging screen zones while the drained supernatant water recycles back to the water dispenser with the aid of the pump's suction. The caked slurry starch discharges into its collector as this unit's scrapper timely grazes its discharging zone.

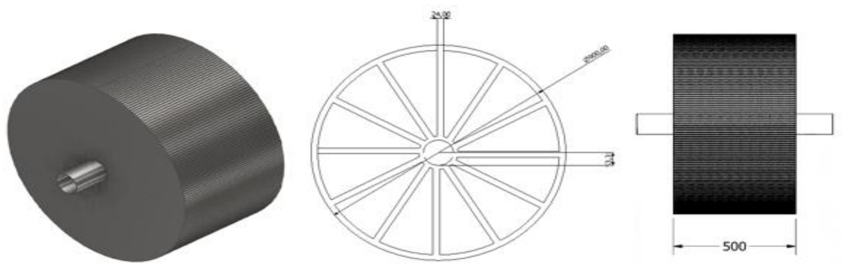


Figure 2: Rotary vacuum drum filter

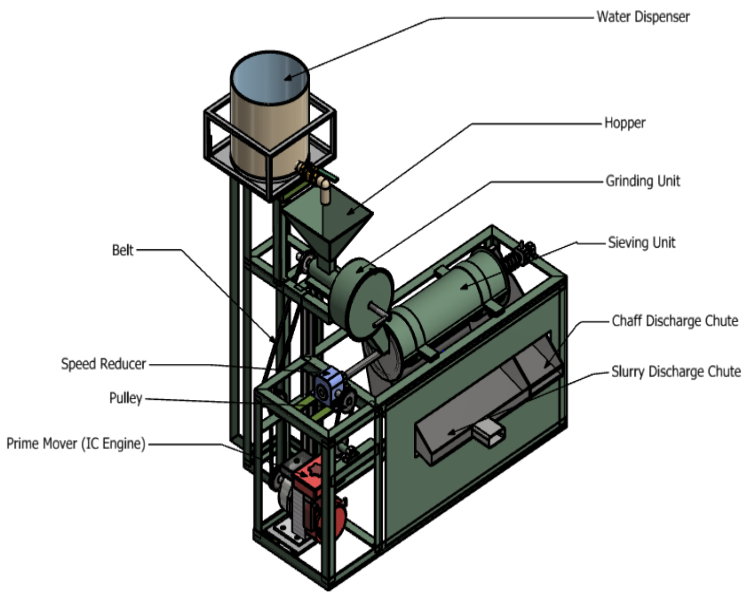


Figure 3. Slurry food milling and sieving machine by [8]

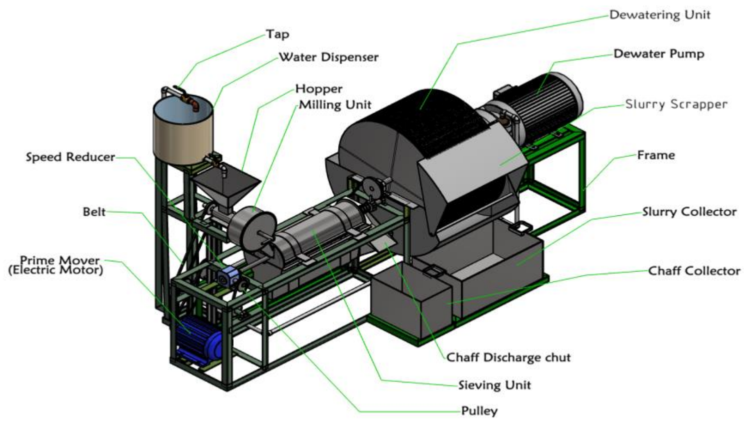


Figure 4. Grain slurry food milling-sieving-dewatering machine.

Design Analysis of the Rotary Vacuum Drum Filter

The rotary vacuum drum filter was designed and developed based on the following considerations:

I. Effective and continuous dewatering of sieved grain slurry filtrate and recycling of the drained water was attained with this system using centrifugal force and vacuum pressure induced by the spinning of its drum and vacuum pump' suction.
II. integration of this filter to the existing milling and sieving machine caused replacement of I. C. engine as its prime mover with an electric motor to enable the operation of its basic units and pump with the same energy source (electricity).
III. All the materials used for the fabrication and incorporation of systems were locally sourced to ensure low cost of production and maintenance.

The rated speed of the electric motor used for driving the mill and speed reducers of the sieve and drum via an intermediate (primary) shaft/v-belts is 1440 rpm while 46:1 and 171:1 constitute the rated gear ratios of the drives 'reducers respectively. The selected drives' pulleys were made of mild steel due to its availability, cost and performance economy. The diameter of all the driving pulleys used in this system is 94 mm each while 94 mm, 150 mm, 140 mm and 120 mm constitute that of the primary, mill, sieve and drum driven pulleys respectively. Thus, the speed of primary, mill, sieve drum shafts were determined as 1440 rpm, 902.4 rpm 20.29 rpm and 0.64 rpm respectively from eq. (1) [15];

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \quad (1)$$

Where N_1 and N_2 constitute driving and driven pulleys speed while D_1 and D_2 are the pulleys' respective diameters.

The conceptual center distances, C, between the adjacent pulleys of the primary and drum drives were determined as 188 mm and 205 mm respectively from eq. (2) while their respective drive belts' lengths were computed from Equation (3) as 671.16 mm and 738.82 mm. Since power transmitted by these drives is less than 3.75 kw, V-belts (type A) with standard pitch lengths of 696 mm and 747 mm were selected for the primary and drum drives respectively [16]. The actual center distances between these drives' adjacent pulleys used in developing the primary and drum drives were also determined from eq. (3) with respect to the selected belts' parameters as 200.42 mm and 204.72 mm respectively.

$$C = \frac{D_1+D_2}{2} + D_1 \frac{D_1+D_2}{2} + D_1 \quad (2)$$

$$L = 2C + 1.57(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4c} \quad (3)$$

The minimum shaft diameters for the primary and drum drives were determined from maximum stress relations for solid and hollow shafts with key ways (eq. 4 and 5) as 23.13mm and 58.17mm respectively [15]. Therefore, the selection of stainless steel solid and hollow shafts with diameters of 25mm and 60mm for the respective drives in line with IS: 2494-1974 standard.

$$d = \left[\frac{16}{\pi\tau}\sqrt{(k_b m_b)^2 + (k_t m_t)^2}\right]^{1/3} \quad (4)$$

$$d_o^3 = \frac{16}{\pi\tau(1-k^4)}\sqrt{(k_b m_b)^2 + (k_t m_t)^2} \quad (5)$$

Where the shear stress for steel shaft with provision for keyway (τ), combined shock and fatigue factor for bending (k_b) and twisting (k_t) constitute 42 N/mm^2, 1.5 and 1.0 respectively while k is 0.5 by [15].

The maximum bending moment (m_b) on the primary and drum shafts were determined from their force analysis (Fig. 5 and 6) as 30483.2 Nmm and 35800mm respectively while their respective maximum twisting moment (m_t) of 7310.85Nmm and 9862Nmm were also determined from the analysis' results using eq. (6) given by [15].

$$M_t = (T_i - T_j)\frac{D_2}{2} \quad (6)$$

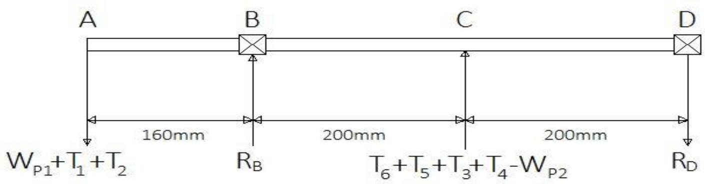


Figure 5. Force diagram of the primary shaft

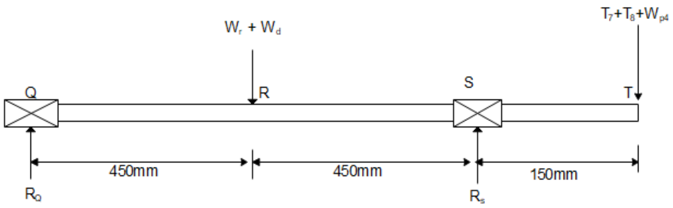


Figure 6. Force diagram of the drum shaft

Where the weights of driven pulleys on the primary and drum shafts are W_{p1}(16.73 N), *and* W_{p4}(16.98 N) while W_{p2} (27.23 N) constitutes the weight of multiple groove driving pulley on the primary shaft through which it drives the mill, sieve and drum shafts. The bearing reactions, R_B, R_D, R_Q, and R_S were determined based on equilibrium of forces on the shafts as 209.91N; 344.05N; 79.78N and 303.35N respectively while the belts' tight side tensions, T_i (T_1, T_3, T_5 and T_7) and their respective slack side tensions, T_j (T_2,T_4 T_6 and T_8) were determined from the following relations given by [15].

$$T_i = T_{max} - T_c \quad (7)$$

$$2.3 log \frac{T_i}{T_j} = \mu\theta \operatorname{cosec} \beta \quad (8)$$

$$T_{max} = \sigma a \quad (9)$$

$$T_c = mv^2 \quad (10)$$

$$\Theta = 180 - [2 \sin^{-1}(\frac{D_2 - D_1}{2C})] \quad (11)$$

$$V = \pi \frac{N_2 D_2}{60} \quad (12)$$

Where, the coefficient of friction (μ), maximum safe stress (σ), mass per unit length (*m*), cross sectional area (*a*) and groove angle (2β) associated with the selected pulleys and belts are 0.3, 2.1 N/mm^2, 0.108kg/m, 81mm^2 and 38° respectively (IS: 2494-1974). The drum weighs, $W_r = 119.23$ N while its slurry carry capacity was determined from eq. (13) as 82.62N.

$$W_d = g\left(0.675\rho_g + 0.075\rho_w\right)\{2\pi r_d h_d[\emptyset_e - \emptyset_i]\} \quad (13)$$

Where, ρ_g (1267.1 kg/m^3) and ρ_w (1000 kg/m^3) are the densities of soaked maize grain and water respectively. The h_d = 0.6m and r_d = 0.45 constitute the width and radius of rotary drum while $\emptyset_e$ (0.855) and $\emptyset_i$ (0.1) are fractional effective (submergence and drying zone) and ineffective (discharge zone) lateral areas of the drum respectively.

The power, P required for the rotary drum filter drive was determined from [15] based eq. (14) as 1.17 kW.

$$P = (T_7 - T_8) \quad (14)$$

Accounting for a total of 2.18 kW required for the mill and sieve drives according [8] and 10% possible power loss due to the drives' friction, the minimum power required for this machine's mill, sieve and drum filter operation was determined as 3.35 kW (4.48 HP). Hence, the selection of a 4.5HP electric motor as sole prime mover for these units' operation.

The bursting pressure of the piping and drum of this filter were determined as 131.7 GPa and 3.37 GPa respectively from Barlow's formula (eq. 15) given by [17] as.

$$P_b = \frac{2St}{D_o S_f} \tag{15}$$

Where, t = 4mm and 3mm are the wall thickness of the pipes and drum respectively while 23mm and 900mm constitute their respectively outside diameter (D_o). The stainless steel ultimate pressure, S = 505MPa and factor of safety, $S_f = 1.5$. Homogeneous deposition of caked slurry starch on the drum's filtration medium starts with constant flow rate while subsequent deliquoring/deposition on top of the initial cake layer increases linearly with pressure drop. The filter's pressure drop constitute a pressure drop across the cake (Δp_c), filtration medium (Δp_f) and drum piping system (Δp_p). The threshold (capillary) pressure of the system (Δp_t) which the applied vacuum pressure (Δp) must exceed to effect the dewatering/dehydration process (displacement of water from the pores) and the power required to drive the pump (P_p) were determined as 58 kPa and 0.48 HP respectively from the following Darcy Welsbach based relations [18].

$$\Delta p_t = \frac{4\sigma_l \cos \theta_l}{D_p} \tag{16}$$

$$P_p = \frac{Q_p \rho_w g H_p}{3.6\times10^6 \eta_p} \tag{17}$$

Where, the pore diameter under vacuum dewatering condition (D_p), surface tension of water (σ_l), contact angle (θ_l), pipe's flow rate (Q_p), acceleration due to gravity (g) and pump efficiency (η_p) are 5μm, 0.73N/m, 0°, $2m^3/hr$, 9.81m/s^2 and 0.8 respectively. The head associated with the piping system (H_p) which constitutes the sum of maximum static head ($H_s = 0.91$m) and dynamic head ($H_D = 1.136$ m) was determined as 2.046 m.

Performance Evaluation Procedure

The milling-sieving-dewatering machine developed was evaluated with five experimental runs to determine the moisture content of slurry starch cake it processed and its through put, extraction efficiency and specific energy consumption. Each test involves processing of maize grains soaked for two days weighing 20kg to slurry starch with this machine to ascertaining the mass of fresh slurry starch cake (M_f).extracted and its moisture content. The moisture content of the cake as per each test was determined by drying one gram of it placed in a foil weighing 0.4 gr with an oven at a constant temperature of 60° C.

The sample was removed from the oven and weighed at every 10 minutes interval until its constant dry weight (W_d) was achieved. Thereafter, moisture content of the food cake was computed using eq. (18).

$$M_C = 100\left(\frac{1.4 - W_d}{W_d}\right) \tag{18}$$

The extraction efficiency (η) of this integrated machine which entails the percentage ratio of the actual slurry starch extracted and the value expected from the process was determined as per each trial from eq. (19) derived based on [19] which specified 15% maximum fibre content for maize grain. The corresponding system's throughput (*TP*) which entails mass of soaked grains processed per hour were computed from processing time measured using eq. (20).

$$TP = \frac{20}{t} \tag{19}$$

$$\eta = \frac{100M_f}{17 + M_c M_f} \tag{20}$$

RESULTS AND DISCUSSION

Performance analysis of the grain slurry food milling-sieving-dewatering machine developed in this study shown in Table 1 revealed that it processed soaked grains to slurry starch with the same throughput of 70.44kg/h and 98.48% extraction efficiency/percentage food loss of 1.52% as its seed milling and sieving machine of [8]. This entails that the integration of this filter did not caused any food loss while saving over 5.39 hours associated the application of mechanized milling and sieving with manual dewatering systems. The survey report by [1] indicated that sedimentation and draining activities in manual gran slurry starch dewatering process takes not less than 0.04 and 0.05 hours per kilogram respectively. This amount to over 0.09 hours per kilogram and 5.39 hours for manual dewatering 59.87kg of grain slurry starch expected from processing 70.44 kg of corn with 15% maximum fibre content as specified by [19].

In addition, the 31.52% moisture content of the starch extracted with this advanced machine also amount to over 10% reduction when compared over 35% cake moisture content associated with manual dewatering systems. Therefore, application of this novel grain slurry food milling-sieving-dewatering machine improves the shelf life/storage potential of grain slurry starch as well mobility due to its weight reduction. Furthermore, water consumption during grain slurry starch production was drastically reduced with this machine because it recycles the water drained after dewatering back to its dispenser for milling and sieving. It also reduced drudgery and improved hygiene through elimination of human contact involved in loading/discharging of intermediate processed grain among the three most strenuous and time consuming unit operations in grain slurry starch processing

Table1. Performance analysis of the grain slurry food milling-sieving-dewatering machine

Run order	Processing time (s)	Slurry food cake extracted (kg)	Cake moisture content (%)	Extraction efficiency (%)	Throughput (kg/h)
1	1022.10	24.44	31.51	98.48	70.44
2	1022.13	24.45	31.53	98.48	70.44
3	1022.12	24.45	31.53	98.48	70.44
4	1022.13	24.44	31.51	98.48	70.44
5	1022.12	24.45	31.52	98.48	70.44
Mean	1022.12	24.28	31.52	98.48	70.44

CONCLUSIONS

A continuous process milling-sieving-dewatering machine was developed in his study for processing of slurry starch from cereal grains. It operates with an average throughput and extraction efficiency of 70.44 kg/hr and 98.48% respectively while 31.52% constitutes the average moisture content of slurry starch cake processed with it. Application of this integrated machine reduced drudgery, food loss and water consumption in this sector. It also improved hygiene as well as the shelf life/storage potential and mobility of the processed grain slurry starch. Thus, the recommendation of this novel integrated machine for effective production of slurry starch from cereal grains.

REFERENCES

[1] Oloyede O. D., Sarafadeen K. S., Fadele O. K. 2016. Trends and Constraints of Grain Slurry Food Processing in Kaduna State, Nigeria. *J. of Biosystems Engineering.* Vol.41(2), pp. 93-97.

[2] Ukwuru M.U., Muritala A., Iheofor A.O. 2018. Cereal Utilization in Nigeria. *Research Journal of Food and Nutrition.* Volume 2 (3), pp. 1-12.

[3] Abdulrahaman A. A., Kolawole O. M. 2006. Traditional Preparations and Uses of Maize in Nigeria. *Ethnobotanical Leaflets*. Vol. 2006 (1), Article 23.

[4] Tugbiyele O. O. 2009. Design of an "Ogi" Processing Plant. Bachelor of Science Project. Department of Mechanical Engineering, University of Ibadan, Nigeria.

[5] Chuanzhong X., Liying C., Pei W., Yanhua M., Ding H. 2012. Development on a Hammer Mill with Separate Sieving Device. *Telkomnika Indonesian Journal of Electrical Engineering*. Volume 10 (6), pp. 1151-1156.

[6] Nwankwojike B. N., Onwuka O. S., Orji N. G. 2015. Design and Development of Integrated Slurry Food Processing Machine. *Innovative Systems Design and Engi.*. Vol.6 (12), pp. 25-32.

[7] Egwuagu O.M., Nwankwojike B. N. 2019. Design Modification and Comparative Evaluation of Integrated Grain Slurry Milling and Sieving Machine. *International Journal of Scientific & Engineering Research*. Volume 10 (1), pp. 1130-1134

[8] Nwankwojike, B. N., Onwuka O. S., Orji N. G. 2019. Development of Slurry Food Milling and Sieving Machine. Patent No: NG/PT/NC/2019/3968. Trademarks, Patents and Designs Registry, Federal Ministry of Industry, Trade and Investment. Abuja.

[9] Tien C. 2006. *Introduction to Cake Filtration: Analyses, Experiments and Applications*. First Edition. Elsevier B.V, Amsterdam.

[10] Anlauf H. (2007). Recent Developments in Centrifuge Technology. *Separation and Purification Technology*. Volume 58. pp. 242–246.

[11] Berk Z. 2013. Centrifugation In *Food Process Engineering and Technology.* Second Edition. Elsevier B.V, Amsterdam, pp. 241-257.

[12] Thom H. 2021. Plant, Equipment and Utilities: Separators and Centrifuges-Applications in the Dairy Industry. Elsevier B.V, Amsterdam. Available through *Reference Module in Food Science*. https://doi.org/10.1016/B978-0-12-818766-1.00132-X. Accessed February, 2021.
[13] Olukunle O. J., Olukunle O. F. 2007. Development of a Sustainable System for Cassava Starch Extraction, in Conference on International Agricultural Research for Development, University of Kassel-Witzenhausen and University of Göttingen, October 9–11, 2007.
[14] Saengchan K., Nopharatana M., Songkasiri W. 2014. Recovery of Tapioca Starch From Pulp in a Conical Basket Centrifuge – Effects of Rotational Speed and Liquid to Solid (L/S) Ratio on Cake Formation and Starch–Pulp Separation Efficiency. *Separation and Purification Technology*. Vol.127. pp. 192–201.
[15] Khurmi R. S., Gupta J. K. 2005. *A Textbook of Machine Design (S. I. Units)*. First Multicolour Edition. New Delhi. Eurasis Publishing House (PVT) Limited.
[16] IS 2494-1974. *Indian Standards.* Indian Standards Institute, New Delhi.
[17] Engineering Tool Box 2005. *Barlow's Formula - Internal, Allowable and Bursting Pressure*. https://www.engineeringtoolbox.com/barlow-d_1003.html. Accessed February, 2021
[18] Engineering Tool Box 2004. *Darcy-Weisbach Pressure and Major Head Loss Equation*. https://www.engineeringtoolbox.com/darcy-weisbach-equation-d_646.html. Accessed February, 2021.
[19] FAO .1992. Maize in Human Nutrition. Available through *FAO Food and Nutrition Series*. http://www.fao.org/nutrition/requirements/archive/en. Accessed February, 2021.

RAZVOJ I OCENA PERFORMANSI INTEGRISANE MAŠINE ZA MLEVENJE-PROSEJAVANJE-ISPIRANJE U PROIZVODNJI ŽITNOG SKROBA

Bethrand Nduka Nwankwojike[1], Osinachi Stanley Onwuka[1], Onyekachi Marcel Egwuagu[2] , Princwil Chibuike Emeh[1]

[1]*Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria*
[2]*Department of Mechanical and Production Engineering, Enugu State University of Science and Technology, Enugu, Nigera*

Apstrakt: Ova studija obuhvata razvoj i integraciju rotacionog vakum filtera u sklop postojeće mašine za mlevenje i prosejavanje kako bi se omogućilo potpuno mehanizovano/kontinuirano mlevenje, prosejavanje, ispiranje i reciklaža vode u proizvodnji skroba od zrna žitarica.

Dobijena mašina za mlevenje-prosejavanje-ispiranje sastoji se od dozatora za vodu, mlina za mlevenje, sita za prosejavanje, rotacionog bubnja, vakuum pumpe od 0,5 hp i 65 kPa i elektromotora od 4,5 HP (3.35 kW) kao glavnih komponenti koje su kontinuirano povezane da bi omogućile protok materijala gravitacijom. Ova integrisana mašina radi sa prosečnim protokom i efikasnošću ekstrakcije od 70,44 kg/čas i 98,48% respektivno, dok 31,52% čini prosečan sadržaj vlage u kašastoj skrobnoj pogači koja se obrađuje.

Inovacija je izazvala uštedu više od 5,39 časova rada i smanjenje sadržaja vlage u skrobu za 10%, uz zadržavanje manje od 2% gubitka hrane povezanog sa mašinom za prosejavanje. Na ovaj način se poboljšava rok trajanja/potencijal skladištenja i mobilnost prerađene skrobne pogače od kaše zrna žitarica.

Potrošnja vode tokom proizvodnje skroba za žitarice je drastično smanjena sa ovom mašinom jer ona reciklira vodu oceđenu nakon odvođenja nazad u dozator za mlevenje i prosejavanje. Takođe je smanjen uložen rad i poboljšana higijena kroz eliminaciju ljudskog kontakta uključenog u utovar/pražnjenje prosečno obrađenog zrna između tri najnapornije i dugotrajne pojedinične operacije u preradi skroba od žitarica.

Zato, postoji preporuka za ovu novu mašinu za mlevenje-prosejavanje-ispiranje kod efikasne proizvodnje skroba od žitarica.

Ključne reči: Zrno žitarica, mlevenje-prosejavanje, ispiranje, mašina za kontinualni proces, skrob od zrna žitarica, dijetetska ishrana/pića od skorba.

Prijavljen: *Submitted*:	**26.08.2021.**
Ispravljen: *Revised*:	**08.01.2022.**
Prihvaćen: *Accepted*:	**25.01.2022.**