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Development and Performance Evaluation of Irish Potato Peeling Machine

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Authors' contributions

This work was carried out in collaboration between both authors. Author AOA initiated, designed, performed the statistical analysis and wrote the first draft of this manuscript. Author MLA supervised and provided all necessary guidance for the study. Both authors read and approved the final manuscript.

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ABSTRACT

An Irish potato peeling machine was developed for use at small-scale/household level. Machine performance evaluation was carried out using three locally grown Irish potato varieties namely; *Nicola*, *Bartita* and *Bawondoya* respectively. A 2^2x3 factorial experiment in completely randomized design (CRD) with three replications was used for evaluation where tuber feed rate, shaft speed and variety were the independent variables and peeling efficiency, tuber flesh loss and machine output capacity were the performance indicators. Analysis of variance (ANOVA) results showed the effects of variety on peeling efficiency and feed rate on output capacity as highly significant (*P=.01*). Also, the interaction of speed and variety on peeling efficiency and the effect of variety on output capacity was significant (*P=.05*). The interaction of variety and speed at 480 rpm achieved a maximum mean peeling efficiency of 55.6% for *Bawondoya*. Similarly, at slightly higher speed of 510 rpm, the maximum mean peeling efficiency of 64.6% was achieved for *Bartita*. Flesh loss value of 0.84% was the least obtained and this was for *Bartita* while the highest flesh loss of 1.43% was observed for *Nicola*. At feed rates of 50 g/sec and 60 g/sec; the minimum and maximum output capacities of 31.3 kg/h and 59.2 kg/h were obtained respectively.

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Keywords: Irish potato; development; design; machine; performance evaluation; peeling efficiency.

1. INTRODUCTION

Irish potato (*Solanum tuberosum L.*) is multifaceted as a staple crop that addresses food security and a horticultural crop for its high value per unit area [1]. A recent statistical data by FAOSTAT [2] indicates that Nigeria recorded an average Irish potato (*Solanum Tuberosum L.*) production to the tune of 1,284,368 tonnes in 2017. Some improved and adaptable varieties such as *RC* 767-2*, RC* 7716-4*, Nicola, Desiree, Kondo, Diamante, Bartita, Kondor, Roslin Ruaka, Lady Christyl* and *Kennebec* were released to farmers by National Root Crop Research Institute (NRCRI) [3]. The demand for fresh Irish potatoes in Nigeria has been largely met locally while the demand for processed products has so far been supplied mainly through imports [4]. Oluwole and Adio [5] reported that drudgery in post-harvest processing can be minimized or eliminated through adequate mechanized processing. The removal of peel is one of the important unit operations for further processing of potatoes in any form [6]. Peeling is an important unit operation in food processing that prepares fruits and vegetables for subsequent processes through removal of inedible or undesirable rind or skin [7]. The main methods for peeling fruits and vegetables are lye peeling, steam peeling and mechanical peeling [8]. Mechanical method is said to have a huge advantage of retaining edible portions of the produce fresh and damage-free [9].

Mechanical peelers can provide high quality fresh final products and they are environmentally friendly and non-toxic. The method is however associated with material loss or peeling loss due to irregular weight, size and shape of produce, variation in the texture of skin/peel, rind and flesh and low flexibility of the machine [10]. Mechanical peeling utilizes abrasive devices, knives, or blades to interact directly with skin and then removes it [11]. The use of abrasive or cutting tools is the most common way for mechanical peeling of fruits and vegetables by applying abrasives on the inside surface of peelers to produce even peeling regardless of uneven surfaces or irregular shape of produce [12]. A 100 kg/h capacity power operated batch type abrasive potato peeler designed by Singh and Shukla [6] achieved a peeling efficiency of 78% and a peel loss of 6%. Similarly, a prototype power driven potato peeling machine using an abrasive principle of peeling was designed and fabricated by Mohammed [13], the evaluation parameters were varied rotational speed, feeding rate and peeling residence time. The optimum peeling efficiency of 52.55%, 87.99% and 98% were obtained at 10, 15 and 20 seconds residence time at a drum speed of 1440 rpm. The methods utilized in Irish potato processing in Nigeria are mostly at industrial or commercial scale; hence, traditional or manual peeling using hand tools remains a viable alternative for small-scale food processors or householders. Apart from the advantages of manual peeling, disadvantages such as loss of useful flesh, injuries and drudgery are regular constraints to the method which are mostly experienced by women and children who are naturally engaged in the activity, hence, an attempt at developing and evaluating the performance of Irish potato peeling machine for use at small-scale level is a welcome idea, this is intended to further ease the drudgery associated with the peeling process.

2. MATERIALS AND METHODS

Irish potatoes with some characteristic properties such as physical, gravimetric, proximate and frictional were taken into consideration in the design of the peeling machine. The selection of potato varieties was based on freshness and availability at the local market. The potato tubers were procured at Yankaba, a local market located in Nasarawa Local Government Area of Kano State, Nigeria. The preliminary and performance tests were conducted in 2019 using laboratory tools and equipment at the crop and processing laboratory of the department of Agricultural and Environmental Engineering, Faculty of Engineering, Bayero University Kano.

2.1 Sample Preparation

Fresh Irish potato varieties namely; *Nicola*, *Bartita* and *Bawondoya* were used for the study. The procured tuber varieties were cleaned and rinsed to remove soil debris, dust and unwanted particles after which they were sorted and kept under cool and hygienic environment.

2.2 Design Considerations

The predetermined properties of the varieties were used as basic design parameters. The power requirement for machine operation was based on static load analysis on the shaft beam. The machine operational speed was varied using speed reduction gears during field experimentation. The selection of construction materials was based on hygiene, corrosive-free characteristics and cost.

2.3 Machine Components Design Computations and Selection

The main components of the machine are (i) hopper (ii) drum shaft (iii) peeling chamber (v) potato outlet (vi) peel outlet and (vii) bearing selection.

2.3.1 Hopper design

The design of hopper was based on volumetric and gravimetric capacities using average axial dimensions and mass ranges. The maximum axial diameters range and average volume were used. Major diameter = 3 x 100 mm; Intermediate diameter = 1.5 x 50 mm and minor diameter = 50 mm and 50 cm^3 (selected).

The volume capacity of cuboid was used.

Hence, Vc = $l \; x \; w \; x \; h$ (1)

where, Vc = Volume of cuboid, mm^3; l = length of cuboid, mm; w = width of cuboid, mm and h = height of cuboid, mm.

Vc =1,125,000 mm^3 = 1125 cm^3

No. of potato/batch = $\frac{volume\ of\ hopper}{Average\ volume\ of\ potato}$ (2)

$= \frac{1{,}125\ cm^3}{50\ cm^3} \approx 23$

Average weight of varieties ranges between 43.2 - 52.8 g.

Hopper full capacity = No. of potato/batch x average weight of potato

= 23 no. x 48 g
= 1104 g.

2.3.2 Shaft size determination

Stainless steel material 316S specification was selected and used.

According to Hall et al. [14], allowable stresses for 316S in ASME shaft code are:

(i) Ultimate Tensile Strength, S_{ult} = 515 MPa and
(ii) Tensile Yield Strength, S_y = 205 MPa

Allowable shear stress for 316S at 30% S_y for torsional stress is smaller to 40% S_y or 24% S_{ult} for bending stress, therefore,

Allowable shear stress, Ss = 0.3 x Sy (3)

Ss = 0.3 x 205 = 61.5 MPa

In accordance with ASME shaft code, allowable shear stress is based on assumption that strength in shear is 75% of strength in tension [15].

Ss = 0.75 x 61.5 MPa = 46.1 MPa.

Shaft diameter equation given by Hall et al. [14].

$$d^3 = \frac{16}{\pi Ss}\sqrt{(KbMb)^2 + (KtMt)^2} \quad (4)$$

where, d = shaft diameter, mm; Ss = allowable stress; Mb = maximum bending moment, Nmm; Mt = torque on shaft, Nmm; Kb = Kt = 1.5 combine shock and fatigue factor applied to both bending moment and torque.

Mt = 2.6Nm (determined)

but, Mt = FR (5)

where, F = Static weight of gear (N) and R = Radius of transmission gear, mm (determined)

Maximum bending moment, Mb = 810.5Nmm (determined).

The shaft beam loading diagram and maximum bending moment diagram are shown in Figs. 1 and 2 respectively.

The shaft diameter was determined thus:

$$d^3 = \frac{16}{\pi(46.1 \; x \; 10^6)}\sqrt{(1.5 * 810.5)^2 + (1.5 * 2.6)^2}$$

d = 8 mm. (A 15 mm shaft diameter was selected due to availability and ease of bearing fitting).

2.3.3 Design of peeling chamber

The design was based on maximum tuber dimensions ranges, shaft drum and brush height. The volumetric capacity of the peeling chamber was determined and used. The peeling chamber is a perforated stainless steel cylinder of inner diameter 180 mm, length 400 mm and 1 mm thickness with two end covers. It houses the shaft drum and the peeling brushes which are alternately mounted on the shaft. A machine casing made from the same material encloses the chamber.

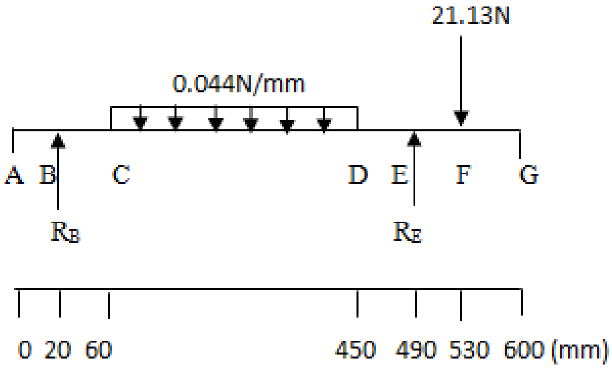

Fig. 1. Load diagram for the shaft beam

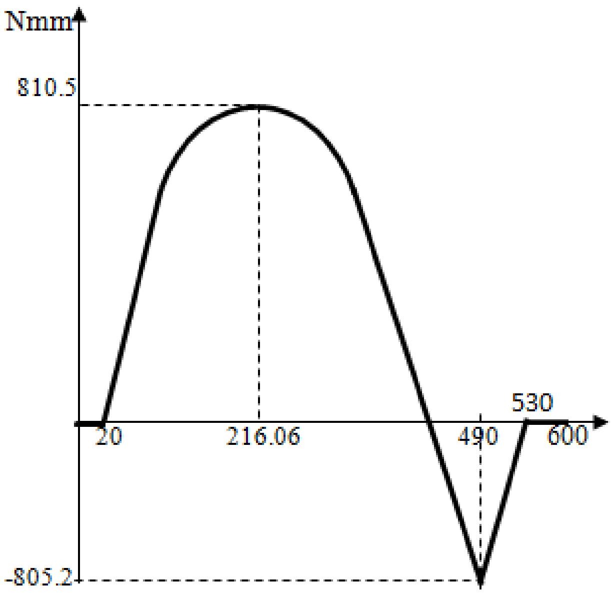

Fig. 2. Bending moment diagram for the shaft beam

The capacity of peeling chamber = volume of hollow cylinder.

$$Vc = \pi h\,(r_o^2 - r_i^2) \quad (6)$$

$$\text{but, } r_i = r_o - t \quad (7)$$

where, Vc = volume of cylinder (mm^3), h = length of cylinder (mm), r_o = outside diameter (mm), r_i = inner diameter (mm), t = thickness of steel (mm)

$Vc = \pi \times 400\,(91^2 - 90^2)\ mm^3$
$Vc = 227{,}480.8\ mm^3 = 227.5\ cm^3$

2.3.4 Design of potato discharge outlet

The discharge outlet for the potato was designed based on measured axial dimensions ranges. It is situated beneath the peeling chamber. It has surface curvature dimensions 120 mm (length) by (100 mm) breadth.

2.3.5 Design of peel outlet

Round perforations of 12 mm diameters were bored on a rectangular stainless sheet before folding to a cylinder. The peel holes size was based on average peel sizes. The number of holes bored on the cylinder was calculated using the formula in [16].

$$\text{Number of holes/1 } m^2 = \frac{1{,}000{,}000}{U^2} \quad (8)$$

where, U = hole equidistance, mm

$$\text{but, } U = R + E \quad (9)$$

R = diameter of hole, mm and E = equidistance interval, mm
R = 12 mm; E = 10 mm (selected)

hence, U = 22 mm

$$A = 2\pi rl \quad (10)$$

where, A = surface area of open cylinder, mm^2; r = radius of cylinder, mm and l = length of cylinder, mm.

$A = 2 \times \pi \times 90 \times 400\ mm^2 = 227{,}088.5\ mm^2$

Number of holes/rectangular area (mm^2) = $\frac{2066\ holes}{10^6} * \frac{227{,}088.5\ mm^2}{1} \approx 469$ holes

2.3.6 Design of peel collection tray

The peel collection tray is a rectangular stainless sheet of dimensions 420 mm by 270 mm by 1 mm. It is situated beneath the peeling chamber at tilt angle 26º. The tilt angle was based on experimented peels sliding pattern on the material.

2.3.7 Bearing selection

The bearing selection was based on basic rating life of bearing at constant speed according to ISO 281 [17].

$$L_{10h} = \frac{10^6}{60n} \left(\frac{C}{P}\right)^{1/p} \quad (11)$$

where, L_{10h} = basic rating life, h: (8000 h, agricultural machines); n = rotational speed, min^{-1}; C = basic dynamic load rating, N; P = dynamic equivalent load, N; p = exponent of life equation = 3 (ball bearing). The highest applied load = 37.7N was used as equivalent dynamic load, P, hence,

$$C = 37.7*\left(8000 * \frac{60 \times 589}{10^6}\right)^{⅓}$$

C = 247.43N

According to SKF [18] bearing data, the dynamic capacity designated 6302-2Z = 11,900N > 247.43N, therefore the bearing was selected.

2.4 Power Requirement and Transmission

The power requirement by the peeling machine is expressed as:

Total power requirement, $P_T = P_d + P_p + P_{gr}$ (12)

where, P_d = power required to drive drum shaft (w); P_p = power required to cause peeling (w); P_{gr} = power required for gear motion transmission (w)

2.4.1 Power required to drive shaft

$$P_d = \frac{2\pi NT}{60} \quad (13)\ [19]$$

and

$$\frac{N1}{N2} = \frac{T2}{T1} \quad (14)$$

where, P_d = power required to drive drum shaft (W), N = N_2 = number of revolution of drum shaft (rpm) = N_2 = 589 rpm (determined from gear velocity ratio); T = torque, Nm

but, $T = Fr_s$ (15)

where, $F = W_d + W_{bs} + Ws$ (16)

r_s = radius of shaft, mm

but W_d = weight of drum, N; W_{bs} = weight of brushes, N; Ws = weight of shaft, N and N_1 = number of revolution of motor pinion (1440 rpm) [20]

T_1 = number of teeth on pinion and T_2 = number of teeth on gear.

F = 3.3 + 3.8 + 8.16 N (determined)
F = 15.26 N
r_s = 7.5 mm = 0.0075 m
T = 15.26 x 0.0075 Nm
T = 0.114 Nm

$$P_d = \frac{(2 \times (3.142 \times 589) \times 0.114}{60}$$

= 7.03 watt

2.4.2 Power required for peeling

The force required to peel periderm of roots as given by Rajput [21].

$$Fp = \frac{\tau}{r_s}\ (N) \quad (17)$$

where, Fp = force required for peeling, N,
τ = torque on shaft, Nm and r_s = radius of shaft, m.

but, Fp = F+ Ff (N) (18)

and

$Ff = \mu N_f$ (19) [22]

where, Ff = frictional force, N; μ = (0.68) static coefficient of friction (determined on stainless steel); N_f = normal force = 10.5N

Ff = 0.68 x 10.5 (N) = 7.14 N

Recall expression 16,

F = 15.26 N
Fp = (15.26 + 7.14) N
Fp = 22.4 N
$22.4 = \frac{\tau}{0.0075}$
$\tau = 0.168$ Nm

$$P_p = \frac{2\pi N\tau}{60} \quad (20)$$

where, P_p = power required for peeling, W; N = drum speed (589 rpm); τ = torque, Nm

$$P_p = \frac{2\ x\ 3.142\ x\ 589\ x\ 0.168}{60}$$

$$P_p = 10.36\ W$$

2.4.3 Gear transmission power

The gear radial force and tangential force equations according to PSG [23] were used for calculating gear power transmission.

$$Pt = \frac{2Mt}{d1} \quad (21)$$

Pr = Pt tan α (22)

where, Pt = tangetial force, N; Mt = torsional moment, Nm; d_1= pitch diameter of gear, m; Pr = gear radial forces, N.

α = 20° (contact angle) [23]

$Pt = \frac{2 \times 2.6}{0.138} = 37.68N$
$Pr = 37.68 \tan 20^0$
Pr = 13.71N

Also,

$Tg = Pr\ x\ r_g$ (23)

where, Tg = torque on gear (Nm) and r_g = radius of gear, m

Tg = 13.71 N x 0.069 m

Tg = 0.95 Nm

$$P_{gr} = \frac{2\ \pi\ NTg}{60} \quad (24)$$
$$P_{gr} = \frac{2\ x\ \pi\ x\ 1440\ x\ 0.95}{60}$$
P_{gr} = 143.28 watt

Total power required for peeling operation:

P_T = (7.03 + 10.36 + 143.28) W

= 160.7 watt ≈ 0.22hp

Fig. 3. Pictorial view of developed Irish potato peeling machine

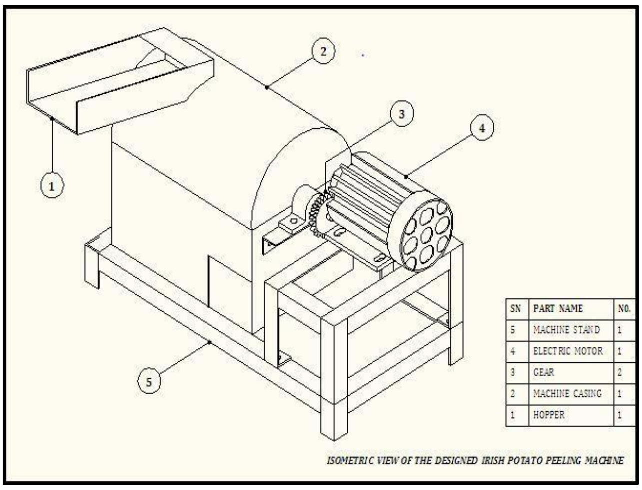

Fig. 4. Isometric drawing of Irish potato peeling machine

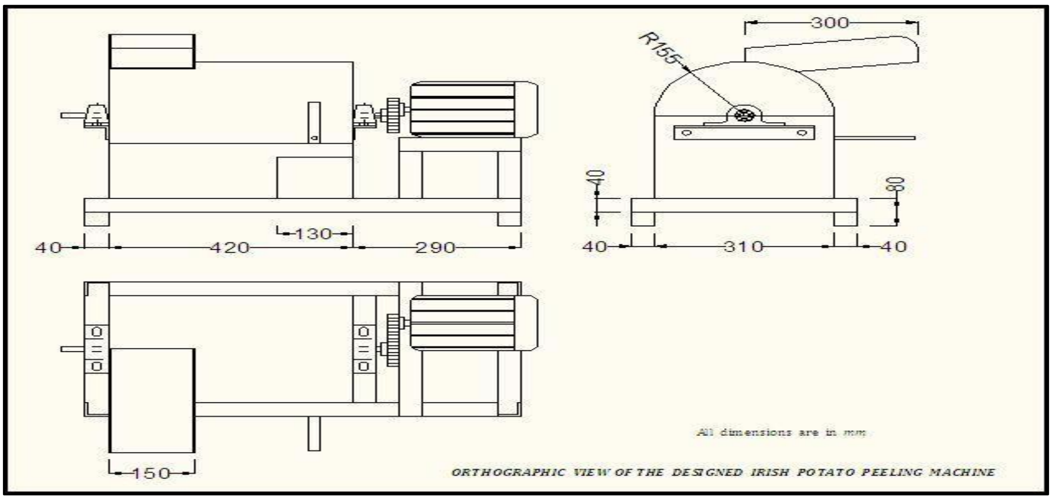

Fig. 5. Orthographic drawing of Irish potato peeling machine

2.5 Selection of Electric Motor

The selection of electric motor was based on specifications, availability and prevailing market cost. A 0.35 hp (0.26 kw) ac induction motor was selected and used in operating the machine.

2.6 Principle of Operation

The power required to operate the machine is supplied by 0.35 hp ac motor. Fresh Irish tubers are batch fed through the hopper at a desired feed rate into the perforated cylindrical chamber while in operation. Torque is transmitted to the shaft which rotates the abrasive brushes mounted on it in the direction of feed. The potato tubers are simultaneously conveyed and peeled by the abrasive action of brushes on the tubers within the perforated chamber for some few seconds after which they are discharged through an outlet. Potato peels pass through the perforations by gravity unto a collection tray situated beneath the peeling chamber. Speed reduction and transmission of power to the shaft is achieved by gear variation and velocity ratio relationship. The pictorial view, assembly and orthographic drawings of the developed Irish potato peeling machine are shown in Figs. 3, 4 and 5 respectively.

3. EXPERIMENTAL PROCEDURE

The moisture contents of sliced samples (varieties) were determined on wet basis using a laboratory Electro-thermal oven (Model DHG, PCD – E3000 series) at 103°C for 8 hours according to Del Nobile et al. [24]. The moisture contents of 80.6% (wb), 79.4% (wb) and 81.4%

(wb) were determined for *Nicola*, *Bartita* and *Bawondoya* respectively. The peel weight proportion was experimented for each sampled variety according to the method utilized by Agrawal et al. [25] and Balami et al. [26] and used as an evaluation parameter. Fresh potatoes of 300 g and 500 g weights were randomly selected from each sample lot and manually peeled to determine the average peel weight proportion. The peel weights relative to sample weights were recorded using electronic balance TH-600 (CS-200-CN) 600 g capacity, 0.1 g accuracy. Table 1 shows peel weight proportion for the three tuber varieties. The machine was evaluated using 300 g and 500 g of the tubers varieties at batch fed rates 50 g/sec and 60 g/sec respectively. A digital Tachometer DT – 2234B (photo-type), 1 - 9999 rpm range was utilized in recording the speed of operation during the peeling process while a microsecond digital stopwatch was used in recording the time taken for peeling to be completed. The weights of peel, peeled potatoes and flesh removed were separately measured for each operation carried out.

3.1 Performance Evaluation of Developed Irish Potato Peeling Machine

The performance of developed Irish potato peeling machine was evaluated using the following indicators:

3.1.1 Peeling efficiency

The machine peeling efficiency was determined using the expression as given by Agrawal et al. [25]

$$\eta p = \frac{Mpo}{Twp} * 100\ (\%) \tag{25}$$

where, ηp = peeling efficiency (%); Mpo = weight of peel collected through peel outlet (g) and Twp = total weight of peel collected by manual peeling (g).

3.1.2 Flesh loss

The expression as given by Nathan and Udosen [27] was used in determining the flesh loss as shown below:

$$F_L = \frac{WFR}{WTF} * 100\ (\%) \tag{26}$$

where, F_L = flesh loss, (%), W_{FR} = weight of flesh removed by machine (g), W_{TF} = total flesh weight of tubers (g).

3.1.3 Machine peeling capacity

The capacity of the peeling machine was determined using 1.0 kg/batch full hopper capacity and noting the peeling time. The expression according to El-Ghobashy et al. [28] was used.

$$Mpc = \frac{Lb}{Tl + Tr + Tu} \tag{27}$$

where, Mpc = machine peeling capacity (kg/hr), Lb = batch load (kg), Tl = loading time (min); Tr = peeling residence time (min) and Tu = unloading time (min).

3.2 Data Analysis

Three Irish potato varieties (*Nicola*, *Bartita* and *Bawondoya*), 2 feed rates (F_1) 50 g/s and (F_2) 60 g/s and 2 shaft speeds, S_1 (480 rpm) and S_2 (510 rpm) were used for performance evaluation of the peeling machine. A 2^2x3 factorial experiment in completely randomized design (CRD) with three replications was used to study the effects of variables and interactions on the machine performance. Data were analyzed using SPSS software and comparison of significance means was by Duncan's multiple range tests (DMRT).

4. RESULTS AND DISCUSSION

The results of data obtained are detailed in Tables 1-9 and discussed under the sub-sections below:

4.1 Peel Weight Proportion

The average peel weight proportion for each variety is presented in Table 1. The peel weight proportion to sample weight is expressed as a fractional equivalent indicated as 0.0276, 0.025 and 0.019 for *Bartita*, *Nicola* and *Bawondoya* varieties respectively.

4.2 Peeling Efficiency

Analysis of variance (ANOVA) data result for peeling efficiency is shown in Table 2. The result showed that peeling efficiency was significantly affected by variety at 1% probability level. The interaction of speed and variety had a significant effect on peeling efficiency at 5% probability level. The interaction of speed S_1 at 480 rpm and variety as indicated in Table 3 show that a maximum mean peeling efficiency of 55.6% was achieved by the machine for *Bawondoya* variety while a minimum of 46% was obtained for *Nicola*.

Similarly, when the machine was operated at a slightly higher speed (S_2) of 510 rpm, a maximum mean peeling efficiency of 64.6% was achieved for *Bartita* while a minimum efficiency of 27.6% was obtained for *Nicola*. Table 4 shows mean ranking with the main effect of variety obtained as 53.3% and 57.9% peeling efficiencies for *Bartita and Bawondoya* (statistically at par) but higher and significantly different from 36.8% efficiency obtained for *Nicola*. This agrees with Mohammed [10] who reported that surface contact of Irish potato with abrasive surface was affected by sphericity of potato, which implies that a more rounded potato is easier to peel than irregular shaped one. The crop varietal differences may have been a possible cause. The highest mean peeling efficiency of 64.6% was attained at $F_1V_2S_2$ (50 g/sec) feed rate; (*Bartita*) and 510 rpm shaft speed combination. This agrees with Talodhikar et al. [20] who reported 64.3% as peeling efficiency at 592 rpm with a similar variety. The minimum mean peeling efficiency of 27.6% was observed at $F_2V_1S_2$ (60 g/sec) feed rate, (*Nicola*) and 510 rpm speed combination. Figs. 6 and 7 show samples of Irish potatoes peeled by the developed machine while Fig. 8 shows sample of peels removed by the machine.

Table 1. Average peel weight proportion

Variety	Potato weight (g)	Peel weight (g)	Average peel weight proportion	Assumed peel weight proportion (g)
Nicola V_1	500	12.5	0.025	0.025W
Bartita V_2	500	13.8	0.0276	0.0276W
Bawondoya V_3	500	9.5	0.019	0.019W

W = quantified weight of Irish potato variety (g)

Table 2. Analysis of variance for machine peeling efficiency

Source	DF	SS	MS	F-value	Pr > F
Fr	1	40.11	40.11	0.19	0.669ns
Va	2	2969.67	1484.8	6.92	0.004**
S	1	92.8	92.8	0.43	0.914ns
Fr*Va	2	38.74	19.37	0.09	0.914ns
Fr*S	1	114.49	114.49	0.53	0.472ns
va*S	2	1522.18	761.09	3.55	0.0448*
Fr*Va*S	2	310.85	155.43	0.72	0.495ns
Error	24	5151.49	14.65		
Total	35	10240.3			

= significant at the 5% level, **= highly significant at 1% level, ns = not significant

Table 3. Result of interaction of variety and speed on machine peeling efficiency

Variety	Speed	Mean	Std error	95% confidence interval	
				Lower boundary	Upper boundary
1	480	46.03	5.981	33.69	58.38
	510	27.55	5.981	15.21	39.90
2	480	51.30	5.981	38.96	63.65
	510	64.60	5.981	52.26	76.95
3	480	55.55	5.981	43.21	67.89
	510	51.10	5.981	38.76	63.46

Table 4. Mean ranking of peeling efficiency with main effect of variety

Variety	N	Subset	
		1	2
Duncan [a.b] 1	12	36.79b	
2	12		53.33a
3	12		57.95a
Sig.		1.000	0.447

Fig. 6. Peeled Bartita

Fig. 7. Peeled Bawondoya

Fig. 8. Sample of potato peels removed

4.3 Percent Flesh Loss

The result of (ANOVA) for flesh loss as presented in Table 5 reveals that variety had significant effect on flesh loss at 5% level of significance. The percent mean flesh loss indicated in Table 6 shows that V_1 (*Nicola*) had the highest flesh loss of 1.43% followed by 1.26% observed for V_3 (*Bawondoya*) which was statistically similar but lower than 1.43%.

Table 5. Analysis of variance for flesh loss

Source	DF	SS	MS	F-value	Pr > F
Fr	1	0.0489	0.0489	0.19	0.667ns
Va	2	2.1765	1.0882	4.23	0.0266*
S	1	0.2187	9.2187	0.85	0.366ns
Fr*Va	2	0.5057	0.2529	0.98	0.388ns
Fr*S	1	0.1009	0.1009	0.39	0.537ns
Va*S	2	0.3397	0.1698	0.66	0.526ns
Fr*Va*S	2	0.1666	0.0833	0.32	0.726ns
Error	24	6.1674	0.2570		
Total	35	9.7243			

***=** *significant at the 5% level, ns = not significant*

Table 6. Mean ranking of flesh loss with variety as Independent variable

Variety	N	Subset	
		1	2
Duncan [a.b] 2	12	0.85b	
3	12	1.267b	1.267a
1	12		1.425a
Sig.		0.056	0.452

Sig. = Significant, [a b] = Mean ranking letters

The least observed flesh loss of 0.84% observed for V_2 (*Bartita*) was statistically similar to 1.26% but significantly lower than 1.43% observed for V_1 (*Nicola*). This agrees with Guwo [29] who reported that material loss decreased with decrease in moisture content of ginger.

4.4 Machine Output Capacity

The (ANOVA) data for machine output capacity is presented in Table 7. The result indicates that the feed rate was highly significant and had an effect on machine output capacity at 1% significant level. Similarly, variety had a significant effect on output capacity at 5% significant level. Further observation of means as indicated in Table 8 shows that at F_2 (60 g/sec) feed rate, a maximum mean output capacity of 59.2 kg/h was achieved while at F_1 (50 g/sec) feed rate, a minimum of 31.3 kg/h was achieved as the mean output capacity. This agrees with findings by Balami et al. [30] and Singh [31] which showed that machine peeling output capacity increased as machine speed increased. The main effect of variety on machine output capacity as shown in Table 9 indicates that with V_3 (*Bawondoya*) and V_2 (*Bartita*) varieties, the output capacities of 47.5 kg/h and 45.9 kg/h obtained were statistically at par but significantly different from 42.3 kg/h obtained for V_1(*Nicola*).

Table 7. Analysis of variance for machine output capacity

Source	DF	SS	MS	F-value	Pr >F
Fr	1	1959037.4	1959037.4	431.2	.0001**
Va	2	46208.6	23104.3	5.09	0.014*
S	1	298.6	298.6	0.07	0.799ns
Fr*Va	2	10723.3	5361.7	1.18	0.325ns
Fr*S	1	1646.1	1646.1	0.36	0.553ns
Va*S	2	9074.6	4537.3	1.0	0.383ns
Fr*Va*S	2	26328.9	13164.5	2.9	0.075ns
Error	24	109034.7	4543.6		
Total	35	2162363.3			

***= significant at the 5% level, **= highly significant at 1% level, ns = not significant*

Table 8. Machine output capacity with varied feed rates

Feed rate (g/sec)	Mean (kg/h)	Std error	95% confidence interval	
			Lower boundary	Upper boundary
50	31.33	15.88	29.26	33.20
60	59.22	15.88	57.25	61.19

Table 9. Mean ranking of machine output capacity with main effect of variety

Variety	N	Subset	
		1	2
Duncan [a.b] 1	12	42.33b	
2	12		45.87a
3	12		47.47a
Sig.		1.000	0.343

Sig. = Significant; [a b] = Mean ranking designation

5. CONCLUSION

Three Irish potato varieties namely; *Nicola, Bartita* and *Bawondoya* were the tuber crops used in evaluating the performance of the developed Irish potato peeling machine. The independent variables used for evaluation were feed rate, shaft speed and variety while peeling efficiency (%), percent flesh loss and machine output capacity (kg/h) were the dependent variables. A completely randomized design (CRD) in 2^2x3 factorial experiments was used and replicated 3 times. The interaction of variety and shaft speed on peeling efficiency was significant at 5% level of probability; similarly, the effect of variety on peeling efficiency was highly significant at 1% probability. The tuber variety had a significant effect on flesh loss at 5% probability level. The effect of feed rate on machine output capacity was also highly significant while variety had a significant effect on output capacity. The highest mean peeling efficiency of 64.6% was obtained at $F_1V_2S_2$ (50 g/s; *Bartita*; 510 rpm) combination while the minimum peeling efficiency of 27.6% was obtained at $F_2V_1S_2$ (60 g/s; *Nicola*; 510 rpm) combination. The least and highest flesh losses were 0.84% and 1.43% for V_2 (*Bartita*) and V_1 (*Nicola*) respectively. The machine output capacities of 31.3 kg/h and 59.2 kg/h were obtained at F_1 (50 g/sec) and F_2 (60 g/sec) feed rates respectively.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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