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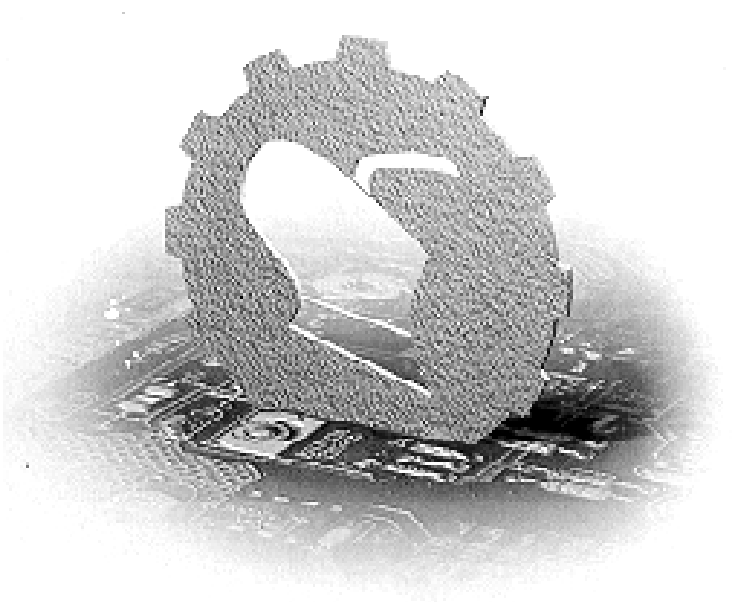

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DETERMINATION OF SOME ENGINEERING PROPERTIES OF IRISH POTATO VARIETIES

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Abstract: Irish potato (*Solanum Tuberosum*) is a nutritive diet in the food chain supply of the Nigerian populace. Apart from the agronomic practices and production level in the country, limited data that exist on engineering properties of the adapted varieties are either scanty or non-existent in print form. Three locally varieties namely *Nicola*, *Bartita* and *Bawondoya* were investigated for some physical and frictional properties using standard laboratory procedures and equipment. The measured parameters are data resource for indigenous processors and machinery and equipment fabricators. The data obtained were subjected to simple descriptive statistics using Microsoft Excel package for computing the mean, range and the standard deviation. The mean, standard deviation and range values for axial diameters (major, intermediate and minor), geometry diameter, sphericity, aspect ratio, mass, volume, density and surface area in varietal order of '*Nicola*', '*Bartita*' and '*Bawondoya*' are (43.61±3.72mm-63.82±7.95mm; 39.41±2.99mm-44.1±2.38mm; 33.41±2.67-5.90±2.87mm); 40.81±1.87mm - 44.02±2.87 mm; 0.70±0.07 - 0.94±0.06; 0.63±0.10 -1.02±0.11; 43.2±4.69g - 52.8±9.9g; 43.3±5.4cm^3-49.8±10 cm^3; 1.001±0.057 g/cm^3-1.065±0.076 g/cm^3 and from43.30±476.20 mm^2 to 6113.63±811.26 mm^2 respectively.
Bulk density values of 701.43 kg/m^3, 673.30 kg/m^3 and 672.86 kg/m^3 were obtained in respective order as above.

Peel-weight proportion of 2.5%, 2.76% and 1.9% were obtained at 80.6%, 79.4% and 81.4% moisture content (w.b) levels for the sampled weight of *Nicola*, *Bartita* and *Bawondoya* varieties respectively.

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The frictional parameters results indicate an angle of repose 15^0 was obtained for both *Bartita* and *Bawondoya* varieties while 13^0 was obtained for *Nicola* variety. Average values of 0.68, 0.61 and 0.52 were obtained as coefficients of static friction for *Bartita*, *Bawondoya* and *Nicola* varieties respectively.

Keywords: *Irish potato, variety, engineering properties, moisture content, sampled weight, parameters*

INTRODUCTION

Irish potato (*Solanum Tuberosum L.*) has been identified to be the fourth most important root crop in Nigeria after cassava, yam and cocoyam with an efficient tuber crop in terms of tuber yield and days of maturity [1]. Its production in Nigeria was estimated to be 1,284,368 tonnes as at 2017 [2]. Improved and adaptable varieties namely; *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].

In Nigeria, most postharvest operations such as sorting, grading, washing, peeling, handling and packaging of products are manually done with the associated drudgery not eliminated. The determination of engineering properties of locally grown 'potato' is important for both educational and research purposes. Engineering properties of locally produced crops form the basis for agricultural machine design, specification and operation. These properties are useful in analysing and determining the efficiency of a machine or an operation in developing new consumer products of plant or animal origin and in evaluating and retaining the quality of the final product [4]. The knowledge of these properties constitutes an important and essential engineering reference in the design of machines, structures, processes and control [5].

The physical properties of agricultural materials are those properties that distinguish them from another. The shape and size are important in the design of metering mechanisms and hopper for any flow process that may be involved while average volume is useful in the design of containment for handling and storage of agricultural products [6]. Particle density of agricultural products has been reported to play significant importance in the design of silos and storage bins [7].

The friction properties are important in the design of equipment for solid flow and structure for storage of biomaterials. The angle of repose and coefficient of friction of agricultural materials of various surfaces are important friction properties to engineers.

The knowledge of coefficient of friction of agricultural materials is important in the design of grain bins, silo and other storage structures while angle of repose is important in cases where bulk material in motion such as movement of solids discharging from bins and hoppers [4].

This research study was carried out in order to determine some engineering properties of three locally grown Irish potato varieties, hence, a resource for indigenous manufacturers and processors.

MATERIAL AND METHODS

Three identified Irish potato varieties namely; *Nicola, Bartita* and *Bawondoya* were used for the study. The selection of tuber varieties was based on freshness and availability while procurement was made at Yankaba, a local market in Nasarawa Local Government Area of Kano State, Nigeria. Some important engineering properties of potato such as the physical and frictional were investigated. The experiments were conducted at the Crop and Processing Laboratory (CPL) of the Department of Agricultural and Environmental Engineering, Bayero University Kano, Nigeria.

Sample Preparation

Twenty five fresh, sorted and clean Irish potatoes from each sample lot were randomly selected and used for each experiment. The samples were number marked to avoid repetition and to eliminate errors during the experiments. The Irish potato varieties are shown in figure 1, 2 and 3 respectively.

Fig. 1. *Nicola* variety

Fig. 2. *Bartita* variety

Fig. 3. *Bawondoya variety*

Experimental Procedure

The experiments were conducted by following specified standard procedures. The parameters such as axial dimensions, geometric diameter, sphericity, aspect ratio, mass, volume, density, bulk density, surface area, peel weight proportion, angle of repose and static coefficient of friction were measured using instruments and equipment such as digital vernier caliper, measuring cylinder, top loading electronic balance, inclined plane apparatus and laboratory oven. Data obtained were subjected to simple statistical techniques using Microsoft Excel package to compute the mean, range and the standard deviation respectively.

Moisture Content Determination

The moisture contents of the Irish potato varieties were determined on wet basis using air-drying electro-thermal oven (Model DHG, PCD – E3000 serials) with temperature range of 100^0C - 500^0C.
Two fresh pieces of potato from each variety were selected and uniformly sliced into 5mm thickness. The sliced samples were subjected to drying at 103^0C temperature for 8 hours [8].

The weights of samples before and after drying were taken at intervals until constant weights were attained. The moisture content relationship by Mohsenin [9] was used in determining the moisture content.

$$MCwb = \frac{Wt - Ws}{Wt} x\ 100\ (\%) \quad \text{……..} \quad (1)$$

where, MC_{wb} = moisture content of sample on wet basis (%);
Wt = total mass of sample before drying (g);
Ws = mass of sample after drying (g).

Figure 4 below shows the air-drying oven model used for the moisture content experiment on the Irish potato varieties.

Fig. 4. Laboratory oven (Model DHG, PCD – E3000 serials)

Determination of Axial Dimensions

The principal axial dimensions (major, intermediate and minor diameters) of each variety were determined using a digital vernier caliper (Elite Inc), 0 - 150 mm range and 0.01mm accuracy. Figure 5 below shows sample of axial diameter reading. The data obtained were used for the computation of the geometric mean diameter, sphericity and surface area using equations (2, 3 and 4) [9, 10]; (5) [11].

$$Dg = (abc)^{\frac{1}{3}} \quad \text{……..} \quad (2)$$

$$Sp = \frac{Dg}{a} \quad \text{……...} \quad (3)$$

$$Sa = \pi(Dg)^2 \quad \text{……...} \quad (4)$$

$$A.R = \frac{b}{a} \quad \text{……} \quad (5)$$

where, a = major diameter, mm;
b = Intermediate diameter, mm;
c = minor diameter, mm;
Dg = geometric mean diameter, mm;
Sp = sphericity;
Sa = surface area, mm^2
A.R = aspect ratio.

Fig. 5. Axial diameter measurement using a digital vernier caliper (Elite Inc)

Potato Mass and Volume Measurement

The mass of 75 Irish potatoes were individually weighed, 25 units from each sample lot were weighed and recorded using an electronic balance (TH–600) 600g capacity with 0.1g accuracy. Figure 6 shows the digital weighing balance utilized for mass measurement experiment.

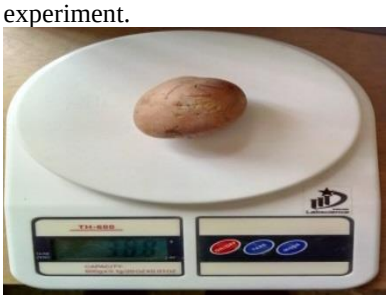

Fig. 6. Digital weighing scale (TH-600)

Fig. 7. Measuring Cylinder (1000 ml)

The volume of the selected Irish potato sample was individually determined for the varieties using water displacement method. Each sample was immersed into the 1000ml measuring cylinder filled with clean water to the 500ml meniscus level. The measuring cylinder shown in figure 7 was used to determine the volume of the potatoes. The increase in the water level was observed and recorded as the volume of the potato.

Determination of True and Bulk Density

The mass of the potatoes were weighed using a top loading digital balance. The true density of each potato variety was determined using the ratio of mass to volume formula (6) [12].

$$D = \frac{M}{V} \quad \left(\frac{g}{m^3}\right) \qquad \text{…….. (6)}$$

where, D = true density, g/cm^3;
M = mass, g;
V = volume, cm^3.

The bulk density was determined for each variety using a graduated plastic container.

The container was filled with Irish potatoes to the brim and weighed using a weighing scale. The bulk density was determined by ratio of bulk mass to bulk volume formula (7) [12]. The bulk mass and volume measurement is indicated in figure 8 below.

$$Db = \frac{Mb}{Vb} \ \left(\frac{kg}{m^3}\right) \qquad \text{…….…….. (7)}$$

where, Db = Bulk density, kg/m^3;
Mb = bulk mass of potato, kg;
Vb = bulk volume of potato, m^3

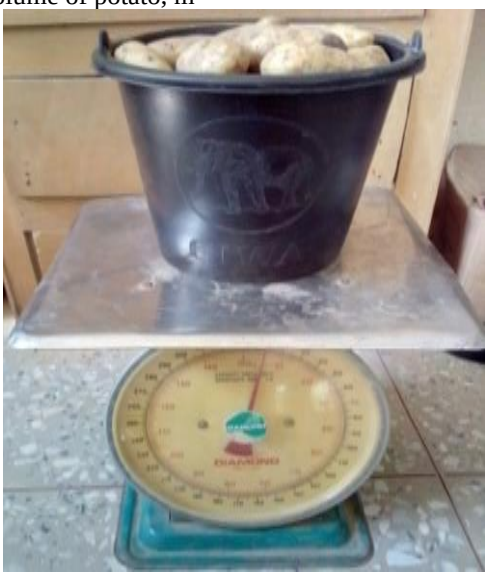

Fig. 8. Bulk mass measurement using a weighing scale (apparatus)

Peel - Weight Proportion

The potato peel weight proportion was determined for the three varieties using the method according to Agrawal *et al.* [13]. Measured mass of 500g potato tubers were manually peeled to ascertain the peel weight in the sample. The average weight of peel to sample mass was determined using the expression (8) [7]. Figure 9 below shows potato–peel weight proportion experiment.

$$Pw = \frac{Mpc}{Ms} \qquad \text{……..…….…….. (8)}$$

where, P_w = peel weight proportion (g);
Mpc = weight of peel collected (g);
Ms = weight of the sample (g).

Fig. 9. Peel-weight proportion determination

Determination of Dynamic Angle of Repose

Randomly selected samples from the lots were individually weighed and placed at a marked point on an inclined plane apparatus after which it was gradually raised until a gradual motion was assumed along the plane. The angle of inclination in degree was read off a protractor attached to the side of the apparatus. The tangent to the angle was determined by mathematical equation (9) [12]. Figure 10 shows the inclined plane apparatus utilized for dynamic angle of repose determination.

$$\text{Tan } \varphi = \frac{h}{r} \qquad \text{..... (9)}$$

where, φ ° = angle of repose;
h = height, cm;
r = length, cm

Fig. 10. Apparatus utilized for dynamic angle of repose experiment

Coefficient of Static Friction Determination

The coefficient of friction experiment for the potato varieties was conducted utilizing the inclined plane apparatus in a horizontal position. The apparatus consists of frictionless pulley fitted on a frame, a needle of negligible weight with thread, load pan and 1mm thick rectangular stainless steel with 560mm length by 100mm breadth as the test surface material.

Weighed potato was made to rest on the test surface with a threaded needle slightly inserted into one end while the thread was looped through the pulley attached to the load pan according to the method utilized by Fadele [14]. Weight of known mass was gradually added to the load pan until the potato assumes a momentary motion along the test surface. The static coefficient of friction apparatus demonstrating the experiment is shown in figure 11. The coefficient of static friction experiment was evaluated by equation (10) [14].

$$\mu = \frac{Ff}{Nf} \qquad \text{..... (10)}$$

where, μ = static coefficient of friction;
Ff = frictional force, N;
N_f = normal force of reaction, N.

Fig. 11. Static coefficient of friction apparatus

RESULTS AND DISCUSSION

The summary of results of physical and frictional properties of the three Irish potato varieties (*Nicola*, *Bartita* and *Bawondoya)* is presented in Tables 1– 4. The moisture contents of the Irish potato varieties were determined on wet basis (wb) as indicated in Table 1. *Bawondoya* variety had 81.4±1.1% moisture content while 80.6±0.4% and 79.4±0.7% were determined for *Nicola* and *Bartita varieties* respectively. The determined moisture content values agree with moisture content range of 63 - 83% according to [15].

Table 1. Physical properties of the three varieties of Irish potato

Physical property	Variety								
	Nicola (80.6%) Mcwb			*Bartita* (79.4%) Mcwb			*Bawondoya* (81.4%) Mcwb		
Parameter	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
			Min Max			Min Max			Min Max
Moisture content, %	80.6	0.40		79.40	0.70		81.40	1.10	
Major dia., mm	63.82	7.95	50.93 88.02	43.61	3.72	35.27 49.99	55.90	6.39	47.00 6939

Contin. Table 1.

Intermed. dia., mm	39.59	3.40	34.04 49.55	44.10	2.38	38.57 47.18	39.41	2.99	31.99 45.38
Minor dia., mm	34.40	2.65	29.55 40.90	35.90	2.87	30.74 43.91	33.41	2.67	28.16 39.59
Geometry dia., mm	44.02	2.87	40.30 49.65	40.81	1.87	36.47 43.29	41.62	1.84	37.83 44.71
Sphericity	0.70	0.07	0.56 0.90	0.94	0.06	0.84 1.03	0.75	0.07	0.64 0.90
Aspect ratio	0.63	0.10	0.46 0.97	1.02	0.11	0.78 1.27	0.71	0.11	0.55 0.93
Mass, g	52.80	9.90	39.50 74.70	43.20	4.69	36.20 52.10	46.50	6.80	36.00 60.00
Volume cm^3	49.80	10.00	40.90 70.00	43.30	5.40	35.00 50.00	45.50	6.60	35.00 60.00
Density, g/cm^3	1.065	0.076	0.956 0.310	1.001	0.057	0.906 1.108	1.02	0.04	0.960 1.100
Surface area, mm^2	6113.63	811.26	5103.53 7745.86	5243.30	476.20	4180.14 5889.16	5453.60	480.80	4495.74 6281.57

S.D = standard deviation, Mcwb = moisture content on wet basis, dia = diameter.

The results of the physical characteristics shown in Table 1 indicate the mean values of axial dimension diameters (major, intermediate and minor), range and standard deviation are 63.82±7.95mm, 50.93-88.02mm; 39.59±3.40 mm, 34.04-49.55mm; and 34.40±2.65 mm, 29.55 - 40.90mm for *Nicola*; 43.61±3.72 mm, 35.27 - 49.99; 44.11±2.38 mm, 38.57–47.18mm; 35.90±2.87mm, 30.74-43.91mm for *Bartita* and 55.90±6.39mm, 47.01 - 69.39mm, 39.41±2.99mm, 31.39-45.38mm; 33.41±2.67mm; 28.16 - 39.59mm for *Bawondoya*. The dimensions obtained agree with the findings by Hamza [16] whose research study is similar to this.

The geometry mean diameter indicates mean values of 44.02mm, 40.81mm and 41.62mm were obtained for *Nicola*, *Bartita* and *Bawondoya varieties* respectively. The sphericity and aspect ratio means of 0.70 and 0.63; 0.94 and 1.02 and 0.75 and 0.71 were obtained for *Nicola*, *Bartita* and *Bawondoya* respectively. Olaoye *et al.* [17] reported that high sphericity and aspect ratio are indicative of fruit tending to the shape of sphere and can be measures of ability of fruit to roll rather than slide on a flat surface, this agrees with the stated observation.

The mass, volume and density mean values indicated as 52.8±9.9g, 49.8±10cm^3 and 1.065±0.076g/cm^3; 43.2±4.69g, 43.3±5.4cm^3 and 1.001±0.057g/cm^3 and 46.5±6.8g, 45.5±6.6 cm^3 and 1.020±0.04g/cm^3 were obtained for *Nicola*, *Bartita* and *Bawondoya* respectively. Similarly, the bulk density determined for *Nicola* was 701.43kg/m^3 while *Bartita* and *Bawondoya* varieties had 673.30kg/m^3 and 672.86kg/m^3 respectively.

The surface area values of 6113.63 mm^2; and 5243.30mm^2 and 5453.60mm^2 were averages obtained for *Nicola*, *Bartita* and *Bawondoya* varieties respectively.

Table 2. Bulk density values for *Nicola, Bartita* and *Bawondoya* varieties

Crop variety (Irish Potato)	Bulk mass (kg)	Bulk volume (m^3)	Bulk density (Kg/m^3)
Nicola	4.91	0.007	701.43
Bartita	4.71	0.007	673.30
Bawondoya (white)	4.71	0.007	672.86

Table 2 shows the result of bulk density determined for the Irish potato varieties. *Nicola* had an average bulk density of 701.43kg/m^3 at 80.6% moisture content (wb); *Bartita* had 673.30kg/m^3 at 79.4% moisture content (wb) and *Bawondoya* with 672.86 kg/m^3 at 81.4% moisture content (wb).

Table 3. Peel weight proportion for the three varieties of Irish potato

Variety	Potato weight (g)	Peel weight (g)	Fractional peel weight proportion	Percent peel weight proportion (%)
Nicola	500	12.5	0.0250	2.50
Bartita	500	13.8	0.0276	2.76
Bawondoya	500	9.5	0.0190	1.90

The results of peel-weight proportion for the potato varieties are shown in Table 3. The percent peel-weight proportion in the measured samples indicates that *Bartita* had 2.76%, *Nicola* had 2.5% while 1.9% was determined for *Bawondoya* variety.

Table 4. Frictional properties of the three varieties of Irish potato

Friction Property	Variety											
	Nicola (80.6%) Mc (wb)				*Bartita* (79.4%) Mc (wb)				*Bawondoya* (81.4%) Mc (wb)			
Parameter	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Repose Angle (º)	13.0	3.1	7.5 - 19.0		15.1	2.5	10.0 - 18.0		15.1	2.5	10.0 - 18.5	
Coeff. of friction	0.52	0.12	0.35 - 0.83		0.68	0.17	0.38 - 0.96		0.60	0.07	0.51- 0.78	

Min = minimum dimension, Max = maximum dimension, Mean = mean dimension, S.D = standard deviation, Mc (wb) = moisture content (wet basis). Coeff = coefficient.

Table 4 displays the mean and minimum and maximum dimension range of angle of repose and coefficient of friction for the frictional properties determined. The angle of repose mean and minimum and maximum range for *Nicola* are 13.0±3.1º, 7.5 – 19.0º while 15.1±2.5º and 10.0-18.5º was respectively determined for both *Bartita* and *Bawondoya* varieties. This agrees with Roy *et al.* [18].

Similarly, the coefficient of static friction mean values 0.52, 0.68 and 0.60 were determined for *Nicola*, *Bartita* and *Bawondoya* respectively. The low values of coefficient of friction agree with Bishop *et al.* [19] who reported that steel material offers lower coefficient of friction (COF) regardless of tuber condition. Klenin *et al.* [20] also reported that potato tubers with COF 0.55 rolls while COF 0.8 slides on metallic surfaces. This is an indication that Irish potato varieties experimented can easily roll on steel surfaces.

CONCLUSIONS

The engineering properties of three Irish varieties namely; *Nicola*, *Bartita* and *Bawondoya* were investigated as a useful resource in research applications. The characteristic properties of the crop varieties were determined at 80.6%, 79.4% and 81.4% moisture contents (w.b) for *Nicola*, *Bartita* and *Bawondoya* respectively. The moisture content values show that the crops which mainly compose of water is susceptible to adverse environmental factors during storage; it is therefore necessary to have important data on its engineering properties for local storage temperature range.

The physical and frictional properties (axial diameters, geometry diameter, sphericity, aspect ratio, surface area, mass, volume, density and bulk density) and (dynamic angle of repose and static coefficient of friction) were determined for the varieties respectively.

The peel weight contents of 2.76%, 2.5% and 1.9% for *Bartita*, *Nicola* and *Bawondoya* varieties are useful in peel content determination, evaluation and separation processes.

The parameters obtained are fundamental resource and data pool for indigenous agricultural machinery designer and fabricators of postharvest handling and processing equipment.

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ODREĐIVANJE NEKIH INŽENJERSKIH OSOBINA IRSKIH SORTI KROMPIRA

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Apstrakt: Irski krompir (*Solanum Tuberosum*) je važna kultura u snabdevanju lanca ishrane nigerijske populacije. Osim agronomske prakse i nivoa proizvodnje u zemlji, ograničeni podaci koji postoje o inženjerskim karakteristikama adaptiranih sorti su ili oskudni ili ih uopšte nema u štampanom obliku.

Za tri lokalne sorte: *Nicola, Bartita* i *Bavondoia*, ispitane su na neke fizičke osobine i karakteristike trenja koristeći standardne laboratorijske procedure i opremu.

Izmereni parametri su izvor podataka za domaće prerađivače i proizvođače mašina i opreme.

Dobijeni podaci su podvrgnuti jednostavnoj deskriptivnoj statistici korišćenjem Microsoft Excel paketa za izračunavanje srednje vrednosti, opsega i standardne devijacije.
Srednja vrednost, standardna devijacija i vrednosti opsega za aksijalne prečnike (veći, srednji i manji), geometrijski prečnik, sferičnost, odnos širine i visine, masu, zapreminu, gustinu i površinu u sortnom redosledu : *Nicola, Bartita* i *Bavondoia* su vrednosti:
od 43,61±3,72 mm do 63,82±7,95 mm; 39,41±2,99 mm do 44,1±2,38 mm; 33,41±2,67 do 5,90±2,87mm; 40,81±1,87mm do 44,02±2,87 mm; od 0,70±0,07 do 0,94±0,06;
od 0,63±0,10 do 1,02±0,11; od 43,2±4,69g do 52,8±9,9g; 43,3±5,4cm^3 do 49,8±10cm^3; od 1,001±0,057g/cm^3 do 1,065±0,076g/cm^3 i 43,30±476,20mm^2 do 6113,63±811,26mm2 respektivno.
Vrednosti zapreminske mase od 701,43 kg/m^3, 673,30 kg/m^3 i 672,86 kg/m^3 dobijene su redosledom kao što je navedeno.
Udeo u težini kore od 2,5%, 2,76% i 1,9% dobijen je na nivoima sadržaja vlage od 80,6%, 79,4% i 81,4% (v.b) za uzorkovanu težinu sorti *Nicola, Bartita i Bavondoia*.
Rezultati vrednosti parametara trenja pokazuju da je ugao mirovanja 15º dobijen i za sorte *Bartita* i za *Bavondoia*, dok je za sortu *Nicola* dobijena vrednost od 13º. Prosečne vrednosti od 0,68; 0,61 i 0,52 su dobijene kao koeficijenti statičkog trenja za sorte *Bartita, Bavondoia i Nicola.*

Ključne reči: Irski krompir, sorta, inženjerske osobine, sadržaj vlage, težina uzorka, parametri.

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A FUZZY-TOPSIS DECISION-MAKING MODEL FOR SELECTIONS OF WETLAND TECHNOLOGY FOR GREYWATER TREATMENT

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Abstract: The use of constructed wetlands for improving greywater treatment by improving nutrient removal at a lower cost than conventional methods has recently attracted renewed interest. The majority of these studies have predominantly pre-defined a wetland configuration for wastewater treatment, which introduces a lot of empiricism in decision-making. To address this problem, this study aims to develop a Decision Support System (DSS) for the selection, design, and optimization of constructed wetlands technologies (CWT) during greywater treatment. To evaluate WT for greywater treatment and determine which physic-chemical and microbial properties need to be treated. A multi-criteria decision-making (MCDM) tool is used simultaneously with a conformity assessment. The DSS was developed after a thorough review of the literature on the design and implementation of various WT (HFWSF, HSSF, VSSF, and VFSF) and greywater characteristics using Microsoft Visual Studio 2010. This study is interesting in that, it integrates contextual data (wastewater characteristics) with WT removal efficiency characteristics to assist you in selecting the best WT.

Typha domingensi and Hyacinth (*Eichhornia crassipes*) were effective at removing contaminants when combined with HFWSF WT. After four-month of study, The HFWSF CWT treatment with hyacinth was found to be effective. for the HFWSF- CWT treatment with hyacinth, the removal efficiency of Faecal coliform, Total coliform, Oil and Grease, Ammonia, Total Phosphate, and COD. 78.46%, 74.33%, 73.08%, 69.23%, 25.29%, and 80% respectively. DSS decision on HFWSF-CWT DSS has demonstrated that it is a competently designed noval dashboard for choosing CWT for the treatment of greywater.

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***Keywords**: Decision Support System, Constructed Wetland Dashboard, Greywater Treatment, Wetland Technology.*

INTRODUCTION

The past two decades have seen increasingly rapid advances in wastewater treatment. of particular concern is the use of constructed wetland technologies as an alternative wastewater treatment system. The technology is increasingly recognized and widely accepted because of its environmental friendliness, frequency of maintenance, and its cost-effectiveness compared to alternative treatment technologies [1]. Artificially constructed wetland plays a significant role in reducing nutrient concentrations, degrading organic compounds, and retaining heavy metals from wastewater, which include sewage waters, mining wastewater, landfills, farmyard runoff, residual dye bath, and municipal wastewater [2].

Several researchers have reported on the results of a constructed wetland that combines saturated vertical flow constructed wetland (VFCW), free drain VFCW and horizontal flow constructed wetland (HFCW. Aside from this, other studies have also focused on other factors that promote plant removal performance, such as the type of constructed wetland and its configuration (vertical, horizontal, surface, or subsurface flow, with or without recirculation. Furthermore, most of these studies have predominantly predefined a wetland configuration for treating wastewater, which introduces a lot of empiricism in decision-making. The authors explore the aspects of the plant's role in wastewater treatment using constructed wetland technologies and greywater from households as a case study.

MATERIAL AND METHODS

Study Area: The experimental evaluation of the wetland technology was conducted at the National Water Resources Institutes (NWRI) premises behind the block of flats opposite the NWRI Demonstration Shonghai Integrated farm (Figure 1). The NWRI is in Kaduna between the latitude 1170473.024 meters and longitude 327176.533 meters, while the wetland construction is at the latitude 1170107.89 meters and longitude 327053.237 meters.

Sample collection: Before subjecting the greywater to this location for treatment, samples of greywater were collected and evaluated.
Samples from wetland technology cells consisting of the treatment of Hyacinth (*Eichhornia crassipes*) and *Typha domingensis* were collected for four months, thus between June 8th to 16th September and August 6th to 28th November 2022, respectively. The greywater samples from both the influent and effluent were collected for physicochemical and biological analysis on two weeks intervals.

Physico-chemical and microbial analysis: The physical, chemical, and microbiological analyses of the greywater sample were conducted. The sample was analyzed immediately, after sample collection, and the rest sample was carried to the laboratory with an icebox for analysis instantly**.**

The selected physical parameters measured onsite include pH, temperature, turbidity (NTU), electric conductivity (EC), and total dissolved solids (TDS) using the palintest pH meters although the other chemical and microbial parameters determined in the laboratory are suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrate (TN), total phosphate (TP). Ammonia (NH_3), oil/grease, total coliform (TC), and faecal coliform (FC). The above mention parameters were analyzed following the standard method of examination of water and wastewater according to the 22nd edition [8] protocols. Table 1 presents the summary of the experiment analysis of fifteen different parameters.

Table 1. Biological and physicochemical properties of greywater/Statistical Analysis

S/N	Parameters	Units	Value	Discharge limits	A significant difference (p-value)
1	pH		6.5	6 – 9	Yes (0.0071)
2	Temperature	°C	23.7	<3°C above ambient	Yes (0.0091)
3	Electrical Conductivity	µS/cm	238	<1500	No (0.0684)
4	Total Dissolve Solid	ppm	119	< 1000	No (0.0787)
5	Turbidity	NTU	73.0	< 75	Yes (0.0215)
6	TSS	mg/l	20	50	Yes (0.0112)
7	BOD	mg/l	20	50	Yes (0.0112)
8	COD	mg/l	600	250	No (0.3333)
9	Total Phosphate	mg/l	2.70	2.0	Yes (0.0495)
10	Total Nitrate	mg/l	3.41	50	Yes (0.0495)
11	Ammonia	mg/l	1.9	1.0	Yes (0.0449)
12	Sulphate	mg/l	42	200	Yes (0.0492)
13	Oil/grease	mg/l	780	5	Yes (0.0333)
14	Total coliform	CFU/100 mL	600	400	No (0.5058)
15	Faecal coliform	CFU/100 mL	130	10	Yes (0.0999)

In the parenthesis is the p-value, with a significance level set at $p < 0.05$.
The p-value for the wastewater characteristics was estimated using MATLAB.

Design Considerations: The following were the steps taken during the development of the DSS for the selection, design, and optimization of constructed wetlands technologies (CWT) during greywater treatment;

1. *The premise for coupling Fuzzy-TOPSIS*
2. *Decision model formulation*
3. *Defining a list of technological alternatives*
4. Identification and screening of assessment attributes (criteria) for selecting the best-constructed wetland technology
5. *Performance modeling of Fuzzy-TOPSIS framework.*

Performance modeling of the Fuzzy-TOPSIS framework

Having looked at objectives, a list of alternative wetland technology, and criteria, we now move to describe the algorithm to be deployed for the decision-making process. The paragraph below represents the steps involved in the framework.

Step 1: Select constructed wetland technology alternatives from the literature.

Step 2: Select evaluation criteria

Step 3: Select fuzzy linguistic variables and their respective fuzzy triangular numbers (or member functions). The linguistic variables and their corresponding TFN used in this study include low (1, 3, 5), moderate (3, 5, 7), and good (5, 7, 9).

Step 4: Aggregate the alternative and criteria weight-age decision matrix.

$$\text{TFN} = (1,3,5) \qquad \widetilde{a_{ij}} = \left(x_{ij}^{k}, y_{ij}^{k}, z_{ij}^{k}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Step 5: Calculate the fuzzy Euclidian distance to the A^{+} and A^{-}

$$M_i^{+} = \sqrt{\frac{1}{3}\sum_{j=1}^{n}\left(m_{ij} - m_j^{+}\right)^2} \qquad i = 1,2,\ldots\ldots,m \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$M_i^{-} = \sqrt{\frac{1}{3}\sum_{j=1}^{n}\left(m_{ij} - m_j^{-}\right)^2} \qquad i = 1,2,\ldots\ldots,m \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2a)$$

Step 6: Rank the alternatives according to relative closeness to the ideal solution

RESULTS AND DISCUSSION

Decision-making dashboard

Figure 1 presents the interface of the application software for determining the optimal constructed wetland technology for treating wastewater. The application software was built based on the models defined in Eq. 1 and 2.

The software was built on two main levels, the first focuses on the characteristics of the greywater, whilst the latter is the characteristics of the wetland technology. This approach introduces robustness in the decision-modeling layer of the software.

The software performs three primary functions (1) estimates which component or pollutant requires treatment; (2) predicts the best CWT by simultaneously considering the pollutants to be treated as well as the characteristics of the technology; (3) presents a visual representation of the proposed technology. The most interesting aspect of this application is its flexibility in allowing the user to enter pollutant parameters readily available. In other words, the user does not need to estimate all the 15 physiochemical and biological characteristics of the wastewater.

Also, the application can estimate any wastewater of interest to the user if the characteristics concentrations are known. Again, because the application was constructed using Microsoft Excel, we can host it on any computer. We can also use it as a standalone software; however, this is beyond this study.

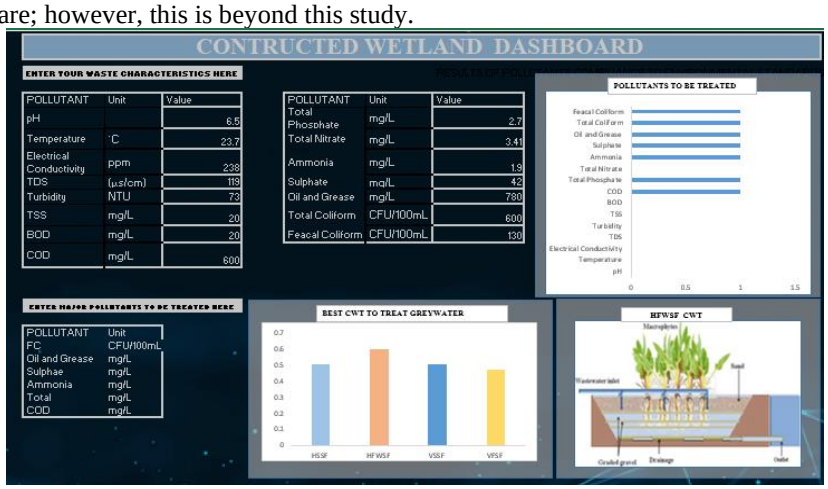

Figure 1. The user interface of the novel dashboard for wastewater evaluation and selection of the best wetland technology

Principles for implementing the decision support system

The development of the novel dashboard presented in Figure 1 is based on integrating two methods. Figure 1 displays an overview of the method used in developing the decision support system.

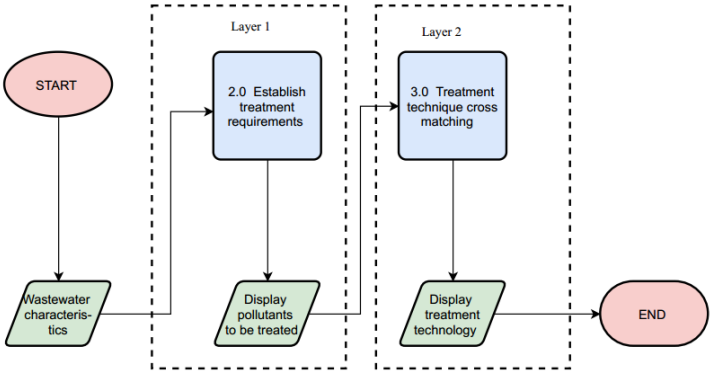

Figure 2. Fundamental layers for building the decision support architecture

The flowchart assumes that the user has conducted experiments to determine the characteristics of the greywater. From Figure 2, we observe the framework has two distinct layers. The first defines a set of characteristics that need to be treated by comparing it to the discharge limits.

The output of the layer focuses on conformity or non-conformity of the pollutant to discharge limits. This serves as an input to the second layer, where the selected pollutants are matched to the predetermined characteristics of wetland technology. 15 parameters were used; however, the application is flexible in that if the user does not have the required parameter, an analysis can still be conducted.

Evaluation of treatment to the proposed technology

Moving on, the recommended Horizontal Free Water Surface Flow constructed wetland was constructed and tested over four months. However, because vegetation is one of the major components for removing pollutants, we selected *Typha domingensis* and water Hyacinth (*Eichhornia crassipes*) for treatment. The vegetation was lowered steadily to increase the plant cover and ensure steady contact with the wastewater throughout the observation period. We measured the concentration change of the pollutants after the 4 months study period against the discharge limits Figures 3 and 4 for the two vegetation). The percentage removal of biological contaminants was obtained from the relation.

$$Contaminant\ removal\ (\%) = \frac{C_{in} - C_{out}}{C_{in}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: C_{in} is the influent concentration

C_{out} is the effluent concentration in mg/L or CFU/100.

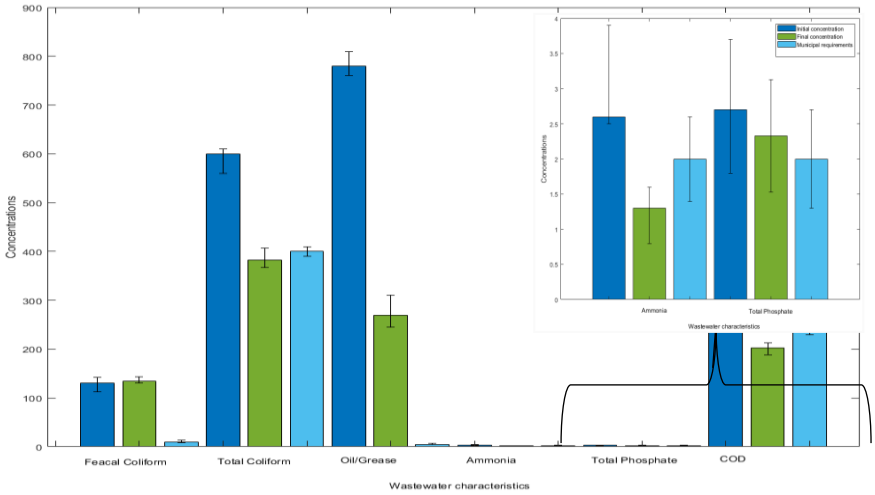

Figure 1. Change in the concentration of contaminants using *Typha domingensis* vegetation

Figure 3, four interesting observations can be made: (1) the selected plant *Typha domingensis* and the engineered technology were relatively effective at removing the contaminants (2) there was no significant change in the concentration of faecal coliform after the four months study period. This implies that *Typha domingensis* was ineffective at the removal of fecal Coliform.

On the contrary, we observe that the total coliform concentration reduces by over 36.33%. Despite this low removal efficiency, it met the municipal requirements. What is surprising is that the concentration of faecal coliform rather increased from 130 CFU/100mL to 135 CFU/100mL. (3) Again, it was relatively effective at removing oil/grease as we observe close to 65.38% removal, although this does not meet the municipal requirements. Although Total Phosphate was somehow removed from the greywater, it was not below the minimum requirements, with a final concentration of 2.33 mg/L (2 mg/L). Howbeit the removal and retention of COD surpassed the municipal requirements with a removal efficiency of 66.17%. This implies that the proposed wetland configuration, as well as the vegetative plant, proved relatively effective in removing two contaminants out of the seven. This result also corroborates strongly with the work of [9], who treated municipal sewage water by deploying a mesocosm scale to remove effectively Total phosphate and COD. Again, the observed results may be attributed to the inherent contaminant transformation potential peculiar to the designed technology. Also, the period used for the study may be contributing factor to the incomplete removal of contaminants in the wastewater.

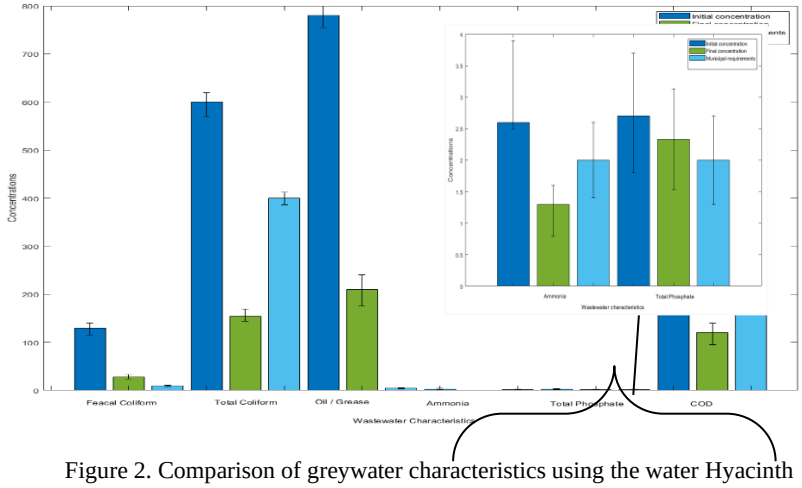

Figure 2. Comparison of greywater characteristics using the water Hyacinth (*Eichhornia crassipes*) vegetation.

Figure 4 compares the relative removal rates of contaminants against the Discharge limits. As can be seen, the removal efficiency of faecal coliform, total coliform, and oil/ grease was 78.46%, 74.33%, and 73.08% respectively. Despite this effective removal rate, Total coliform was the only contaminant among the above three that met the municipal removal requirements. The incomplete removal of these contaminants is consistent with the current literature presented by [10], which achieved 72% and 76% removal of total coliform and faecal coliform, respectively. On the contrary, the other two contaminants were out of the range of the limit of reuse according to [11]. This may be attributed to the shorter period used for the study. What stands out in this Figure 4 is that Ammonia, Total Phosphate, and COD were simultaneously removed effectively with a removal rate of 69.23%, 25.29%, and 80% respectively.

This result is somewhat counterintuitive as the results correlate with the work of [12], [13] who tested raw domestic wastewater using HFWSF in an in-situ application to effectively remove COD, BOD, Ammonia, and Total Phosphate in China and Italy, respectively.

Experimental model validation (Treatment for conform and non-conform)

So far, the study has shown the effectiveness of the proposed model-based framework in selecting a constructed wetland technology, and in treating greywater. In this section, we demonstrate the dynamic behavior of the Horizontal Water Free Surface Flow constructed wetland over four months.

Three interesting observations can be made. First, we observe that Water hyacinth *(Eichhornia crassipes)* has a greater contaminant removal potency than *Typha domingensis*. This is evidenced by its profiles lying below that of *Typha domingensis*. Again, with COD, we observe that water Hyacinth *(Eichhornia crassipes)* removal efficiency reached a maximum peak of about 500% removal efficiency between weeks 8 and 9. Similar observations can be made for the other contaminants.

Second, with water Hyacinth *(Eichhornia crassipes*), a consistent decrease in the concentration of contaminants is observed except for the total Sulphate and Ammonia. Again, we see that after week 4 and week 8, the pollutant removal remains consistent. These results may be due to the maximum biomass growth achieved by the plant, hence the steady nutrient absorption rate. Also, such a level shows a need to change vegetation plants as perhaps a maximum biomass limit had been achieved. On the contrary considering, the *Typha domingensi*, an inconsistent removal rate was observed. One unexpected finding was the removal of faecal coliform by *Typha domingensis.* We observe a steady decrease in concentration, howbeit, the final concentration did not differ significantly from the initial concentration. The results imply that water Hyacinth *(Eichhornia crassipes)* is efficient in municipal WWT and corroborates strongly with the work of [14], [15] who tested the performance of wetlands using water Hyacinth *(Eichhornia crassipes*).

Turning now to dynamics of change in contaminants that met the discharge limit. These include pH, temperature, total coliform, fecal coliform, turbidity, and total dissolved solids. What is surprising is the consistent fluctuations in the concentration, especially for turbidity and total dissolved solids. This inconsistency may be due to the environmental conditions since we experimented in an open place.

Contrary to expectations, a significant difference between the initial and final concentration for all parameter cases.

CONCLUSIONS

The experiment conducted confirmed that the novel Constructed Wetland Dashboard was useful in determining the components of greywater to be treated and effective in predicting CWT to treat the greywater based on its characteristics. An implication of this is the possibility that the dashboard will be adopted by key stakeholders and engineers during the user-specific design of constructed wetland technologies.

Also, one of the more significant findings to emerge from this study is how the engineered wetland using water Hyacinth (*Eichhornia crassipes*), proved effective in removing four of the seven contaminants. Howbeit, because of the shorter time in which the experiment was not all contaminants were completely removed.

The results of the study indicate that it is worth investing in constructed wetland technologies for greywater treatment, however, the dashboard presented can go a long way in improving wastewater-specific wetland technology design. Whilst this study did not confirm the absolute removal of contaminants such as oil/grease, faecal coliform, and total coliform, it did partially substantiate the need for additional technology.

In addition, stakeholders can use the novel methodological framework and decision support dashboard developed with Microsoft Excel when planning the design and implementation of the technology in other communities.

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FUZZI-TOPSIS MODEL ODLUČIVANJA ZA IZBOR TEHNOLOGIJE TRETMANA OTPADNIH VODA IZ MOČVARA

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Apstrakt: Korišćenje formiranih močvara za popravku tretmana otpadnih voda poboljšanjem uklanjanja otpadnih materija po nižoj ceni od konvencionalnih metoda, nedavno je privuklo novo interesovanje. Većina ovih studija je pretežno unapred definisala konfiguraciju močvarnog područja za tretman otpadnih voda, što unosi mnogo empirije u donošenje odluka. Da bi se rešio ovaj problem, ova studija, ima za cilj da razvije sistem za podršku odlučivanju (DSS) za odabir, projektovanje i optimizaciju izgrađenih tehnologija močvara (CWT) u toku tretmana otpadnih (sivih) voda.
Da se proceni WT za tretman otpadnih voda i odredi koje fizičko-hemijske i mikrobiološke osobine treba tretirati, alat za donošenje više kriterijuma (MCDM) se koristi istovremeno sa ocenjivanjem usaglašenosti.

Sistem DSS je razvijen nakon detaljnog pregleda literature o dizajnu i implementaciji različitih tretmana WT (HFVSF, HSSF, VSSF i VFSF) i karakteristika otpadnih voda koristeći programski paket Microsoft Visual Studio 2010.
Ova studija je zanimljiva po tome što integriše najvažnije podatke (karakteristike otpadnih voda) sa karakteristikama efikasnosti uklanjanja WT kako bi pomogli u odabiru najboljeg tretmana voda (WT).
Rogoz *(Tipha domingensis*) i zumbul (*Eichhornia crassipes*) bili su efikasni u uklanjanju zagađivača u kombinaciji sa HFWSF WT.
Posle četiri meseca istraživanja, ova studija HFWSF je utvrdila da je CWT tretman zumbulom efikasan. Za HFWSF-CWT tretman zumbulom, efikasnost uklanjanja fekalne koliformne, ukupne koliformne, ulja i masti, amonijaka, ukupnog fosfata i COD. 78,46%, 74,33%, 73,08%, 69,23%, 25,29% i 80% respektivno.
Odluka DSS o HFWSF-CVT DSS je pokazala da je kompetentno dizajnirana nova kontrolna metoda za odabir CWT za tretman otpadnih voda.

Ključne reči: *Sistem za podršku odlučivanju, izgrađena kontrolna tabla za močvare, tretman otpadnih voda, tehnologija za močvare.*

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ODREĐIVANJE EMISIJE GASOVA STAKLENE BAŠTE KOD MOTORA TRAKTORA U LABORTORIJSKIM USLOVIMA

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Sažetak: Upotreba fosilnih goriva značajno pogoršava probleme globalnog zagrevanja zbog emisije ugljen-dioksida, i ostalih gasova sa efektom staklene bašte. Korišćenje poljoprivrednih mašina sa dizel motorima ima svoj negativan doprinos u ovoj emisiji štetnih gasova, jer se traktori ne koriste samo kao radne i vučne mašine, već i na putevima za prevoz robe i ljudi. U ovom radu je izvršeno merenje emisije štetnih gasova u simuliranim uslovima (laboratorija) rada motora traktora IMT 539 i IMT 542, kao tipičnih predstavnika traktora snage motora do 50 kW u Srbiji. Određivanje količine emitovanih gasova, ugljen dioksida (CO_2), azotnih oksida (NO_x) i ugljovodonika (HC) je izvršeno tehnikom infracrvene spektrometrije sa Furijeovom transformacijom (FTIR) sa protočnom gasnom ćelijom. Na ovaj način je izvršena korelacija parametara potrošnje dizel goriva, režima rada i emisije štetnih gasova u simuliranim radnim uslovima specifičnim za ovaj tip traktora. Rezultati ispitivanja jasno ukazuju na zavisnost povišene emisije CO_2, NO_x i HC od režima rada traktora.

Ključne reči*: traktor, poljoprivredne mašine, ugljen-dioksid, emisija gasova staklene bašte, životna sredina*

UVOD

Jedan od najvećih globalnih ekoloških problema je povezan sa rastućim zagađenjem ambijentalnog vazduha i globalnim zagrevanjem koje nastaje zbog povećane emisije gasova sa efektom staklene bašte (GHG).

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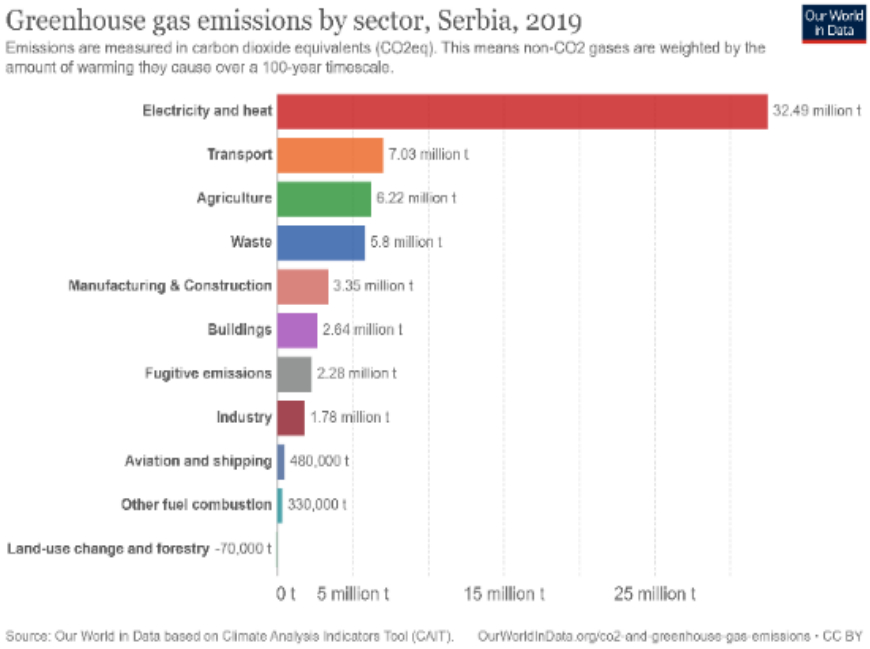
Najčešći sastojak GHG je ugljen-dioksid (CO_2), a približno 96% svih emisija CO_2 je rezultat sagorevanja fosilnih goriva [1].
Povećanje globalne koncentracije CO_2 je na drastičnom nivou i iznosi oko 2 ppm godišnje u 2000-im [2], i koncentracija je dostigla čak 400 ppm [3], a za posledicu ima povećanje prosečne temperature na Zemlji za oko 1 $^{\circ}$C, što nije konačna vrednost.

Opšti trend globalnog razvoja poljoprivrede je ka automatizovanim tehnologijama i snažnijim i produktivnijim pogonskim, samohodnim mašinama [4]. Ovaj trend stvara smanjenje troškova poljoprivredne proizvodnje i povećava konkurentnost na globalnom tržištu. Ipak, upotreba traktora sa većim snagama dizel motora i poljoprivrednih mašina ima i negativne uticaje na životnu sredinu kroz povećanu emisiju GHG [5].

Trenutni uslovi proizvodnje i ekološki zahtevi primoravaju proizvođače da nalaze načine za smanjenje potrošnje goriva i emisije štetnih izduvnih gasova. Iako su u prethodnom periodu postignuta značajna dostignuća u smanjenju potrošnje goriva i štetnih izduvnih gasova u novim vozilima i traktorima, broj ovih vozila se ubrzano povećava, što umanjuje benefite postignute uštedama [6,7].

Od ukupne emisije GHG, prema sektorima upotrebe u Srbiji za 2019. godinu, najveći doprinos imaju proizvodnja električne energije i toplote (52%), transport (11%) i poljoprivreda (10%) [8], (Slika 1).



Slika 1. GHG emisije po sektorima u R.Srbiji za 2019. godinu. [8].
Figure 1. GHG emissions by sector in R.of Serbia in 2019. [8].

Važan deo emisija GHG gasova iz dizel motora potiče od radnih mašina kao što su poljoprivredni traktori i slično. Traktori stariji od 10 godina su odgovorni za 25-40% svih izduvnih gasova iz off-road tipa vozila [9].

U R.Srbiji postoji između 410.000 i 450.000 registrovanih traktora [11], od kojih su tradicionalno najpopularniji traktori domaćeg proizvođača, i to modeli IMT 533, IMT 539, i IMT 542.

IMT je bila domaća fabrika poljoprivrednih mašina koja je za 60 godina postojanja proizvela 780.000 traktora [11]. Veliki broj ovih traktora je i dalje u upotrebi, jer su izuzetno laki za rukovanje, pokretljivi i okretni, i na tržištu postoji velika količina rezervnih delova.

Slika 2. Traktor IMT 539 i IMT 542, [11].
Figure 2. Tractor IMT 539 and IMT 542, [11].

Ipak, određivanje emisije GHG gasova iz traktora se ne može izračunati uzimajući prosečne faktore emisije GHG, kao u slučajevima putničkih vozila i dr. Ovi prosečni faktori ne uzimaju u obzir opterećenje pri vršenju operacija, transport robe i ljudi traktorom, niti starost i stanje dizel motora. Prilikom dizajniranja domaćih traktora kao što je IMT 539, glavni cilj je bio da korisnik (poljoprivrednik) treba da dobije maksimalno radno iskorišćenje, a ne da smanjuje emisije GHG, posebno kada obavlja teške poslove kao što su oranje ili drljanje. Količina izduvnih gasova koja proizilazi iz određene operacije zavisi od motora i karakteristike opterećenja [12]. Na opterećenje motora mogu uticati alternativne tehnike vožnje, dizajn pogona i dr. Rezultati istraživanja [13,14] pokazali su da u svim slučajevima emisije CO_2 direktno zavise od potrošnje goriva, prateći trend rasta sa porastom potrošnje. Ako se procesom sagorevanja, dizel gorivo u motoru potpuno iskoristi, izduvni gas će sadržati ugljen-dioksid (CO_2), vodenu paru (H_2O) i azot (N_2). Međutim, u realnim uslovima unutar dizel motora, dizel gorivo delimično sagoreva te sadrži i druge GHG, poput ugljen monoksida (CO), azotne okside (NO_x), ugljovodonike (HC) i čestice (PM) [15].

Ovaj rad se bavi ispitivanjem emisije GHG gasova iz korišćenih traktora IMT 539 i IMT 542. Ova dva modela su odabrana kao predstavnici velikog broja malih traktora u Srbiji starosti preko 20 godina. Emisija GHG je određivana kontinualnim merenjem sastava izduvnih gasova u simuliranim uslovima rada traktora, odnosno pri različitim brojem obrtaja kolenastog vratila motora. Dobijeni rezultati su korelisani sa izmerenom prosečnom potrošnjom dizel goriva za ova dva modela traktora.

MATERIJAL I METODE

U ovoj studiji su korišćeni mali traktori i to modeli IMT 539 i IMT 542 (Slika 2.), proizvedeni 1996. godine, u funkcionalnom radnom stanju, i registrovani.

Tehničke karakteristike [16].ispitivanih motora traktora su date u Tabeli 1.

Tabela 1. Tehničke karakteristike traktora; Table 1. The Characteristics of the used tractors

Model	IMT 539	IMT 542
Karakteristika Characterictics		
Radna zapremina motora (cm^3) Engine volume (cm^3)	2500	2500
Masa praznog vozila (kg) Empty vehicle mass (kg)	1780	2090
Snaga pogonskog agregata (kW) Engine power (kW)	29,5	31

Ispitivanje je rađeno u simuliranim radnim uslovima u laboratoriji opremljenoj za ovakva ispitivanja motornih vozila. Traktor je podignut na dvostubnu hidrauličnu dizalicu, nosivosti 4t (Nantong Balance Mechanical & Electronic Co, Ltd.). Radni uslovi su simulirani tako što je broj obrtaja motora mehaničkim putem održavan na 500, 1000, 1500 i 2000 min^{-1}, tokom 2 časa, za svaki korak.

Kontinualno merenje emisije GHG je vršeno pomoću prenosnog infracrvenog spektrometra sa Furijeovom transformacijom (FTIR), opremljenog gasnom protočnom ćelijom (Gasmet DX4015), Slika 3.

Slika 3. Izgled FTIR spektrometra Gasmet DX4015 sa gasnom ćelijom.
Figure 3. FTIR spectrometer Gasmet DX4015 with gas cell.

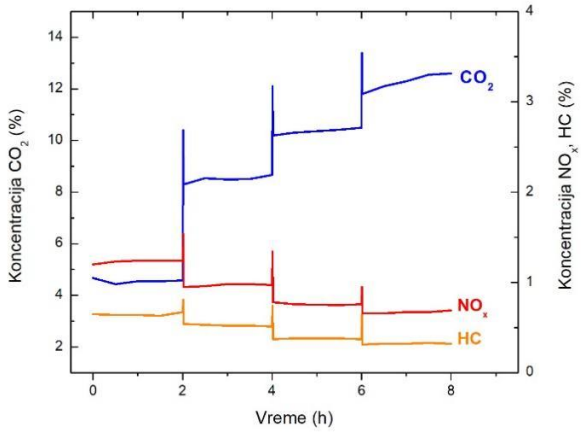
Gasna ćelija je izrađena od aluminijuma visoke čistoće koji je presvučen rodijumom i dizajnirana tako da je ukupni put gasa kroz ćeliju dužine 9.8 m. FTIR spektrometar ima visoku rezoluciju talasnih dužina od 8-4 cm^{-1}, sa učestanošću skeniranja od 10 sken/s. Vrednost izabranog protoka ispitnog gasa određuje brzinu odziva FTIR uređaja, čija je vrednost < 1s, za veoma niske koncentracije i protoke. FTIR spektrometar je kalibrisan za ispitivanje velikog broja zagađujućih i toksičnih gasova. Ovim merenjem određivane su koncentracije CO_2, NO_x i HC (ukupnih uglovodonika), izražene u zapreminskim procentima (%). Ukupne količine emitovanih GHG gasova su određene merenjem protoka gasova u izduvnoj grani motora traktora .

Određivanje prosečne potrošnje dizel goriva je izvršeno merenjem mase traktora bez vozača sa punim rezervoarom, pre početka testa, i mase traktora bez vozača, nakon testa, korišćenjem nagazne vage nosivosti 6 t, model WWS C6T (DINI ARGEO).

Na ovaj način se iz razlike mase i poznavanja gustine dizel goriva može izračunati njegova zapremina, te podeliti sa ukupnim vremenom trajanja testa.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Radi ispitivanja emisije GHG, a pre početka merenja, motor traktora, IMT 539 i IMT 542, je bio startovan kako bi postigao radnu temperaturu, i kako bi se izbegli efekti neravnomernog rada motora i njihov uticaj na emisiju GHG. Potrošnja goriva je izračunata deljenjem razlike mase traktora na početku i na kraju testa, sa vremenom rada motora. Masa traktora pre početka testa merena je nakon postizanja radne temperature, te se na takav način potrošnja goriva do tog momenta nije uzimala u obzir.
Na Slici 4. je dat protokol testiranja rada traktora, odnosno simulirani uslovi rada.

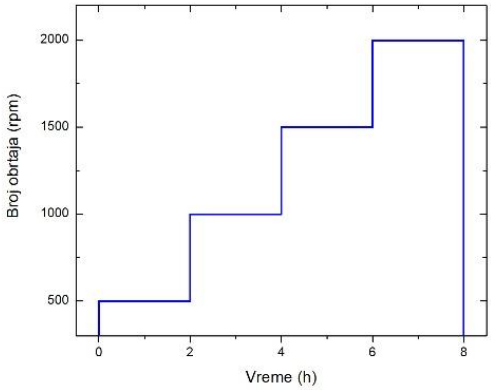


Slika 4. Protokol testiranja rada ispitivanih traktora.
Figure 4. Testing protocol of investigated tractors.

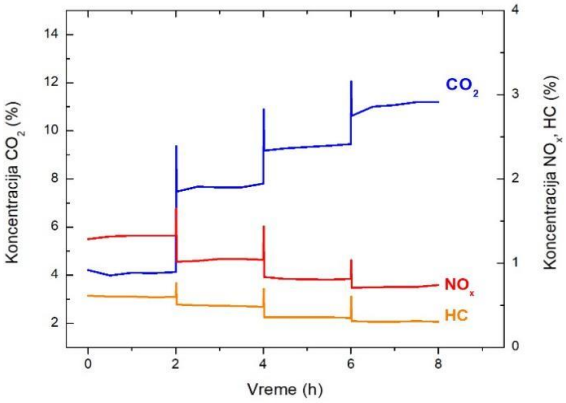
Ovaj protokol testiranja je dizajniran tako da simulira radne uslove traktora IMT 539 i IMT 542, tokom 8 časova rada, aproksimirajući vreme rada u praznom hodu kod 500 min^{-1}, vreme prevoza tereta kod 1000 min^{-1}, kao i vreme rada na njivi kod 1500 i 2000 min^{-1}. Na ovaj način je izraženo ukupno radno vreme od 8 h tokom jednog dana.

Na Slici 5a) i 5b) su prikazani rezultati kontinualnog merenja emisije CO_2, NO_x i HC tokom simuliranih uslova rada motora traktora.

a)



b)



Slika 5. a) Emisije GHG iz traktora IMT 539 i b) emisije GHG iz traktora IMT 542.
Figure 5. a) GHG emissions form tractor IMT 539 and b) GHG emission from tractor IMT 542.

Dobijeni rezultati pokazuju značajnu emisiju CO_2 u izduvnim gasovima, za oba ispitivana traktora, IMT 539 i IMT 542, gde je jasno uočljivo da koncentracija CO_2 dostiže čak i 14%. U oba slučaja vidljivi su pikovi promene koncentracije CO_2 kada dolazi do nagle promene broja obrtaja kolenastog vratila motora, u skladu sa protokolom testiranja datim na Slici 4.

Koncentracija CO_2 raste sa porastom broja obrtaja kolenastog vratila motora, što je i očekivano jer je tada povećana potrošnja goriva. Najniža emisija CO_2 je pri najnižim brojem obrtaja kolenastog vratila motora (500 min^{-1}), tj u režimu praznog hoda, a najviša pri visokim vrednostima broja obrtaja kolenastog vratila motora, tj. u režimu rada na njivi.

Koncentracije NO_x i HC prate obrnuti trend, smanjujući se pri povećanju broja obrtaja motora, što ukazuje na bolje iskorišćenje dizel goriva.

Imajući u vidu izmerene vrednosti koncentacija GHG gasova u realnom vremenu, moguće je izračunati prosečnu emisiju svakog od ovih gasova, izraženu po času rada. Ovi rezultati su prikazani u Tabeli 2.

Tabela 2. Prosečne emisije GHG po času, za traktore IMT 539 i IMT 542
Table 2. Average hourly GHG emissions for tractors IMT 539 and IMT 542

Model	IMT 539	IMT 542
Emisija GHG po času GHG emissions per hour	(kg/h)	
CO_2	15,5	14,4
NO_x	0,0015	0,0012
HC	0,0010	0,0010

Ukupne prosečne emisije GHG su u bliskoj korelaciji sa prosečnom potrošnjom goriva, koja je određena iz razlike mase ispitivanih traktora pre i posle testa, Tabela 3.

Tabela 3. Prosečna potrošnja goriva po času, za traktore IMT 539 i IMT 542
Table 3. Average fuel consumption for tractors IMT 539 and IMT 542

Model	Masa pre testa (kg) Mass before test (kg)	Masa posle testa (kg) Mass after test (kg)	Prosečna potrošnja goriva (L/h) Average fuel consumption (L/h)
IMT 539	1824	1790	4,5
IMT 542	2139	2111	4,2

Izračunavanjem prosečne potrošnje dizel goriva se može uvideti da manja potrošnja goriva znači i manju emisiju CO_2, što je i očekivan rezultat. Ovi rezultati dalje pokazuju da emisija CO_2 kod ispitivanih traktora nije zanemarljiva, te da na dnevnom nivou može iznostiti oko 0.1 t CO_2, a uzimajući godišnji nivo upotrebe ovakvih traktora, procenjeno na 50 punih radnih dana, ovo iznosi oko 5t CO_2 po traktoru.

Kada se uzme u obzir da su u ovom radui ispitivani traktori starosti preko 20 godina, kao i da su najzastupljeniji modeli od oko 400.000 registrovanih traktora [11], ove emisije nisu zanemarljive. Takođe, ispitivani traktori ovog tipa imaju dizel motore relativno male snage do 50 kW, dok traktori sa većim vrednostima snaga dizel motora imaju i značajno veću potrošnju goriva, i emisije GHG gasova u atmosferu.

ZAKLJUČAK

U ovom radu su prikazani rezultati merenja emisije gasova sa efektom staklene bašte kod traktora IMT 539 i IMT 542, u simuliranim radnim uslovima (laboratorija). Radni uslovi su postavljeni tako da simuliraju različite režime rada, od praznog hoda do najvećeg broja obrtaja kolenastog vratila motora tokom 8 časova rada.

Ispitivanje emisije CO_2, NO_x i HC je vršeno kontinualno tokom ovih testova prenosnim FTIR spektrometrom sa gasnom ćelijom.

Dobijeni rezultati pokazuju da koncentacije CO_2 rastu sa porastom broja obrtaja kolenastog vratila motora, tj. da veću emisiju CO_2 ovi traktori imaju tokom rada na njivi. Emisije NO_x i HC opadaju sa porastom broja obrtaja motora, što je posledica boljeg iskorišćenja dizel goriva. Merenje mase traktora IMT 539 i IMT 542 pre i posle testa je omogućilo određivanje prosečne potrošnje dizel goriva po času rada.

Utvrđeno je da su emisije GHG u bliskoj korelaciji sa količinom potrošenog dizel goriva, te da njihove prosečne količine po času rada mogu značajno doprinositi ukupnim količinama emitovanog CO_2 u atmosferu.

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DETERMINATION OF THE GREENHOUSE GASES EMISSION FORM OF USED TRACTORS IN LABORATORY CONDITIONS

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Abstract: Utilization of fossil fuels significantly worsens the problems of global warming due to the emission of carbon dioxide and other gases with the greenhouse effect. Agricultural machinery with diesel engines has its own negative contribution to this emission of harmful gases, because tractors are not only used as working and traction machines, but also on roads for transporting goods and people. In this work, the emission of harmful gases was measured in simulated operating conditions (laboratory) of used tractors IMT 539 and IMT 542, as the most typical representatives of tractors with engine power up to 50 kW in Republic of Serbia.
Determination of the amount of emitted gases, carbon dioxide (CO_2), nitrogen oxides (NO_x) and hydrocarbons (HC) was performed using the technique of Fourier transform infrared spectrometry (FTIR) with a flow gas cell. In this way, the parameters of diesel fuel consumption, operating mode and emission of harmful gases were correlated in simulated working conditions specific to this type of tractor.
The test results clearly indicate the dependence of increased CO_2, CO, NOx and HC emissions on the tractor's operating mode.

Key words: *Tractor, agricultural machinery, carbon dioxide, greenhouse gas emissions, environment*

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ASSESSMENT OF IRRIGATION WATER QUALITY AND SELECTED SOIL PARAMETERS AT MANKESSIM IRRIGATION SCHEME, GHANA

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Abstract: Irrigation has become very critical in acquiring an all year round crop production. The aim of the research work was to assess the irrigation water quality and selected soil parameters at the Mankessim irrigation scheme, which is used to irrigate all types of crops within Mankessim and its environs. The data of the study was collected from two sources, from water and soil samples. Water samples were collected from three different surface water sources within the scheme for both the dry and wet seasons. Nine (9) different samples were collected for each season, three (3) samples for each surface water source. Also, six (6) different soil samples were collected for each season. Soil samples were collected from an irrigated and non-irrigated farm lands. The results of the study indicated that water sources, that is from surface sources did not differ significantly from each other comparing the dry and wet seasons and that their chemical values were within the limits acceptable for irrigation and crop production. The concentrations (Na, Ca, Mg, EC and TDS) were fairly within the permissive limits for crop water use.

Keywords*: Irrigation water quality, Salinity, Total Dissolved Solids*

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INTRODUCTION

A drastic increase in irrigation activities was witnessed during the post –World War II and has contributed substantially to the massive growth in the agricultural production that enables humanity to feed its doubling population [1]. However, a distinction has to be made between the overall positive contribution of irrigation and water to agricultural productivity and economic welfare and a significant amount of misallocation and management of resources that have accompanied the expansion of irrigation. According to Khanom and Salehin [2], soil salinity is a normal hazard in many parts of coastal areas, affecting different uses of water including irrigation, drinking, household, fisheries, and functioning of the ecosystem. If there is any harmful chemical component, it can affect the irrigation system through wear and tear and the plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients [3],[4], [5]. It must also be emphasized that irrigation systems which are the mechanisms that allow water to be diverted from its original place to be applied to the agricultural fields for supplementing water for crop growth and enhancing yields [6], could also be affected by soil water salinity. Irrigation water quality is related to its effects on soils and cultivated crops and its management [7]. High-quality crops need high-quality irrigation water keeping other inputs optimal. Haque [8] analyzed that the severity of the salinity problem in coastal areas increases with the desiccation of the soil. Salinity intrusion due to sea-level rise will decrease agricultural production through the unavailability of fresh water and soil degradation [9].

Increasing demands of food grain by ever increasing population has resulted in the over utilization of water resources. However, an appropriate evaluation of the water quality prior to its use in irrigation will help in arresting any harmful effect on plant productivity and ground water recharge. The issue of irrigation water quality is still not properly addressed. The fertility needs, irrigation system performance and longevity and how the water can be applied contribute to irrigation water quality. Crops cannot grow properly if the irrigation water is not of good quality.

Also, soil may lose its fertility if the irrigation water is highly saline. The productivity of farmers who use such water for irrigation will reduce. It is therefore important for the farmers to know the chemical composition of the irrigation water to enable the irrigation engineer to know the chemicals that might be affecting the irrigation system and the crop, and hence reducing their yield. Hence this study was conducted to assess the quality of water used for irrigation and to determine the levels of selected chemical properties of soils in irrigated and non-irrigated parts of the Mankessim irrigation scheme in the Central Region of Ghana.

MATERIALS AND METHODS

Study area

The water and soil samples as well as other related data collected were carried out over the period between December –March, 2018 (dry season) and from April – July, 2019 (wet season) in Mankessim (Fig. 1). The Mankessim irrigation scheme is located around latitude 5^{O} 18' - 5^{O} 20' N and longitude 1^{O} 02' - 1^{O} 04' W at Barfikrom (Mankessim) in the Mfantsiman district in the Central Region of Ghana.

The project has as head-works an earth dam constructed in 1978 and is designed for gravity and sprinkler irrigation systems. The Mankessim irrigation project is used by farmers within Mankessim and its environs for irrigations of their vegetables.

Figure 1. Map of Central region within which Mfantseman district is located

Climate of Mankessim

Mankessim has a tropical climate. The average temperature in Mankessim is 26.7℃. Precipitation here averages 1150 mm. The driest month is January, with 23 mm of rainfall. Most of the precipitation here falls in June, averaging 275 mm. The warmest month of the year is March, with an average temperature of 28.1℃. August is the coolest month, with temperatures averaging 24.4 ℃. The difference in precipitation between the driest month and the wettest month is 252 mm throughout the year while temperatures vary by 3.7 ℃.

Geography and Soil of Mfantseman Municipal District

Mankessim is within the Mfantseman Municipal which is located along the Atlantic coastline of the Central region of Ghana and extends from latitude 5^{O} to $5^{O}20'$ north of the equator and longitudes $0^{O}44'$ to $1^{O}11'$ west of the Greenwich Meridian, stretching for about 21 kilometers inland and constituting an area of 612 square kilometers. According to FAO [10] and Effland et al. [11] the area is characterized by Savannah ochrosols. Soils along the river banks and irrigated sites are loose clay. Some areas possess silt deposits. Loose fertile silty loam is found further from the river.

Vegetation type and topography of Mfantseman Municipal District

According to the Ministry of Food and Agriculture, Ghana, two major vegetation types are found. On the upland is the coastal shrub while the flood plains are characterized with grasses growing to a height of about two meters. Land is undulating and about 60 m above sea level. Major streams and rivers are Narkwa, Bruku, Ochi and Amisa.
Flood plain areas lie below 60 m above sea level.

Water samplings and analysis

Water sampling procedure and analysis
The water samples were collected from three surface water sources used by the farmers. The samples were collected in both the wet and dry seasons.

Three water samples each were collected from the surface water which was used for irrigating crops at three identified points within the catchment area and labelled as surface water 1, surface water 2 and surface water 3. The samples collected were kept in thoroughly washed containers and covered to avoid the contamination which might affect the analysis.
The samples were collected during the wet and dry seasons and were analyzed for pH (Using pH meter), Electrical Conductivity (using the EC meter), Sodium (using salinometer), Iron, Total Dissolved Solids, Total Suspended Solids, Nitrate, Calcium, and Magnesium.

Determination of Iron
For the determination of iron in the samples that were provided, Iron Cell Test Kit from Spectroquant in the Test Kit all the iron ions present in the samples were reduced to Fe^{2+} ions by ascorbic acid. In the presence of the medium thioglycolate, a purple complex was formed because Fe^{2+} react with a trizine derivative. The complex was determined photometrically by using UV-Vis spectrophotometer.

Determination of Total Dissolved Solids
Conical flasks were washed with distilled water and labelled with respect to the water samples. The initial weights of the conical flasks were determined on a weighing balance. A filter paper was then placed in a funnel and placed into the conical flasks. 10 ml of each water samples were filtered and placed into the oven for 24 hours. The final weights of the conical flasks and dissolved solids were determined on the weighing balance. The difference in weight represented the amount or quantity of dissolved solids in each of the water samples.

Determination of Total Suspended Solids
The initial weight of the filter paper was determined and labelled with respect to each of the water samples. After filtering each of the water samples, the filter paper contained the suspended solids are folded neatly and placed in the oven over night. The final weight of the filter paper containing the suspended solids are determined. The difference in weight represents the quantity of suspended solids contained in each of the water samples.

Determination of Nitrate
Beakers were washed and rinsed with distilled water. The beakers were then oven dried for an hour. 10 ml of each of the water samples were pipetted into each of the beakers with respect to the numbering on the water samples. The samples were then placed into the fume chamber for some time. 2 M sodium hydroxide was prepared. 1ml each of acid was placed in each of the beakers. After 20 minutes, the sodium hydroxide was added. Standards of 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 were oven dried.

Sodium hydroxide was added to each of the prepared standards to reach 25 ml given either a light or deep yellow coloration. The visible spectrophotometer was used to determine each of the nitrate.

Determination of Calcium and Magnesium
Two separate experiments were conducted simultaneously. One for the determination of calcium only, and calcium and magnesium combined. Using 250 ml beakers, the filtered water samples were lined from 1 to the last sample. 50 ml of distilled water was added to 100ml of water filtered in each sample. 15 ml of ammonia buffer was added to each of the samples in the 250 ml beaker for only the calcium and magnesium combined experiment. 1ml of 5% HAHC was added to all the samples. 1ml of 1% RCN was added to all the samples. 1ml of 4% $K_4Fe(CN)_6$ was added to both experiments. 1ml of triethanolamine was added to all the samples in both experiments. 20 ml of sodium hydroxide was added to the samples for determining calcium only. 0.005 M EDTA was titrated against the calcium and magnesium experiment after adding EBT indicator. 0.005 M EDTA was titrated against calcium only after adding calcium indicator. The difference in the values of the calcium and magnesium experiment and the calcium only experiment gave the values for the Magnesium.

Soil Samplings and Analysis
Some soil properties were studied by collecting soil used by farmers for the production of some vegetables like lettuce and tomato grown in the catchment area. The soil samples were collected from two small scale farmers' fields. Both farmers use the water sources identified within the catchment area for their irrigation. Soil samplings were done at different depths using an auger. The soil samples collected were kept in containers. They were then transported to the laboratory for drying, sieving and analysis. Soil analyses were carried on the soil samples after drying the samples in the laboratory and then sieved in a 2 mm sieve and then analyzed afterwards. The chemical properties that were determined included pH and electrical conductivity. The pH was measured for both the dry and wet seasons using the pH meter and the electrical conductivity was also determined using electrical conductivity meter.

RESULTS AND DISCUSSION

Water Sample Analysis
Water samples were collected from surface water sources in both dry and wet seasons in Mankessim (Baafikrom) and were analyzed for various chemical properties shown in Tab. 1 for the dry season and Tab. 2 for the wet season.

Chemical analysis of surface water sampled in the dry and wet seasons
The results shown in Table 1 are measurements of chemical analysis of surface water from Mankessim sampled in the dry season.
The results show the mean for each parameter analyzed. The chemical analysis of this surface water sampled during the dry season was slightly acidic according to the pH (6.58-6.79) and sodium contents were found to be relatively high. The total dissolved solids (10.0-15.0 mg/L) with a mean value of 9.21 mg/L were found to be within the acceptable limits of irrigation water quality for tomato and onion production [12], [13] and [14]. However, continued use of this water for irrigation, may increase soil alkalinity.

Surface water analysis from Mankessim area during the wet season

The chemical analysis of water samples from surface water sources in Mankessim during the dry season is shown in Tab. 1 in comparison with Tab. 2, where sampling was done in the wet season, the pH of the water in wet season was slightly acidic, with a mean reading of 5.59. The magnesium contents were also slightly elevated above those in the dry season with a mean of 4.29. However, for nitrate, the values were lower (0.52 mg/L) than those analyzed during the dry season (2.06mg/L). This would suggest that the wet season water was slightly acidic compared to the dry season water due to the presence of nitrogen oxides in the precipitate and probably from the dissolved anions from the underlying rocks during percolation [15].

Like water sampled during the dry season, this water also could have no negative effects on soil properties and on crops. Therefore, it can be used for irrigation without any tangible problems [16].

Table 1. Comparison of physicochemical parameters with FAO guidelines in the dry season.

Season		FAO Irrigation Guidelines				DRY SEASON		
Location		Degree of restriction on use				Surface water 1	Surface water 2	Surface water 3
	Parameters	None	Slight-moderate	Severe	Unit	Mean	Mean	Mean
	pH	Normal range 6.5-8			-	6.58	6.58	6.76
	EC	<0.7	0.7-3.0	>3.0	dS/m	0.21	0.192	0.238
	TSS	<50	50-100	>100	mg/l	8.83	6.23	2.75
	TDS	<450	450-2000	>2000	mg/l	10	15	10
	Na	<3	3-9	>9	mg/l	9.09	9.09	9.47
	Ca		0-20	>20	me/l	7.01	5.81	3.46
	Mg		0-5	>5	me/l	4.96	4.61	3.31
	Fe	<0.1	0.1-1.5	>1.5	mg/l	0.38	0.35	0.34
	NO_3	<5	5-30	>30	mg/l	0.31	0.75	0.49
	SAR		0.5-15	>15		3.39	3.32	4.72

Table 2. Comparison of physicochemical parameters with FAO guidelines in the wet season.

Season		FAO Irrigation Guidelines				WET SEASON		
Location		Degree of restriction on use				Surface water 1	Surface water 2	Surface water 3
	Parameters	None	Slight-moderate	Severe	Unit	Mean	Mean	Mean
	pH	Normal range 6.5-8			-	5.75	5.64	5.39
	EC	<0.7	0.7-3.0	>3.0	dS/m	0.171	0.179	0.179
	TSS	<50	50-100	>100	mg/l	1.5	1.75	15.85
	TDS	<450	450-2000	>2000	mg/l	15	35	35
	Na	<3	3-9	>9	mg/l	6.06	7.19	7.58
	Ca		0-20	>20	me/l	2.8	4.6	3.7
	Mg		0-5	>5	me/l	2.91	2.43	2.19
	Fe	<0.1	0.1-1.5	>1.5	mg/l	0.52	1.09	1.73
	NO_3	<5	5-30	>30	mg/l	0.75	2.43	3.01
	SAR		0.5-15	>15		5.66	5.31	5.99

Comparison of the Chemical Properties of the Water Sources

From the results obtained from the three water sources and seasons as recorded in Tab. 1 and Tab. 2, it shows clearly that there were no differences in EC, TDS, and TSS data, in both seasons. However, some of the parameters had differences in the wet season but not in dry season, which includes pH, Fe, and NO_3 in the dry season while other parameters had differences dry seasons for example, TSS and Ca. This could be a reflection of water source origin as influenced by the weathering of parent materials, and differences in seasonal depositions from the atmosphere [17].

Comparison of the Sodium Absorption Ratio of the water sources for wet and dry Season.

The SAR is an indicator of the amount of sodium (Na) in the water relative to calcium (Ca) and magnesium (Mg). A situation that hampers permeability affects the fertility and it reduces the crop yield. The dry season water samples analyzed had a lower Sodium Absorption Ratio compared to the wet season samples. The maximum sodium absorption ratio recorded in the dry season samples was the surface water 3 giving SAR of 4.72 and the minimum being surface water 2 which was 3.32. Also, the minimum Sodium Absorption Ratio recorded for the wet season was surface water 2 giving SAR of 5.31 and the maximum being surface water 3 which is 5.99. Even though the SARs for both the dry and wet seasons fell within the acceptable FAO range, water will be readily available to the plant roots when irrigated in the dry season than the wet season. This is because of the high sodium content in the wet season compared to the dry season which, its effect may manifold as specific ion toxicity to sodium sensitive plants, impaired soil drainage and plant nutrition imbalance or deficiencies in the plants as stated by Hussain [18]. When irrigated in the wet season, there is an increase in the exchangeable sodium content on soil exchange complex and disperses the soil more rapidly affecting crop and yield. There is also the possibility of high soil pH resulting in lock of phosphates, iron and other micronutrients as well as dispersion of clay and slit particles in the soil which may collapse the soil structure and blocking soil pores thereby the resulting effect on reducing the effectiveness of irrigation.

Comparison of the Total Water Salinity of the water sources for wet and dry Seasons

From the results, the total water salinity of the surface water sources for both the dry (Fig. 2) and wet seasons (Fig. 3) were within the FAO acceptable range since salinity is analyzed using either the electrical conductivity or the Total dissolved solids [18]. Irrigation during the wet season has salinity content compared to the dry season. The maximum electrical conduction and Total dissolved solids for the dry season are 0.238 and 15 respectively while those of the wet season are 0.59 and 35 respectively. This indicates that the salinity contents of the surface water sources are higher during the wet season compared to the dry season. The soil salinity increases in direct proportion to the salinity of irrigation water and the depth of water applied, hence the plant growth reduces during the wet season as compared to the dry season.

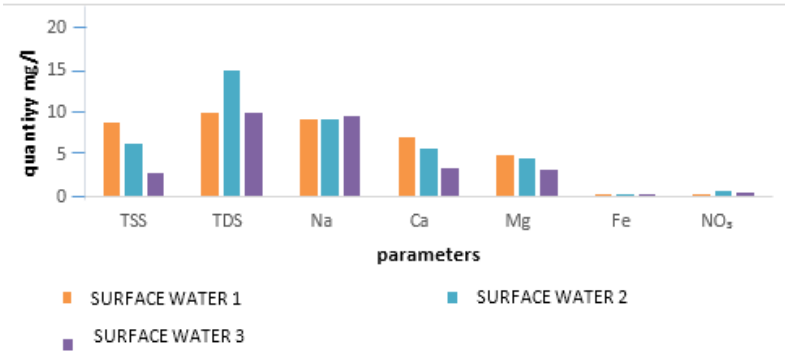

Figure 2. Water quality analysis from surface water sources in Mankessim during the dry season

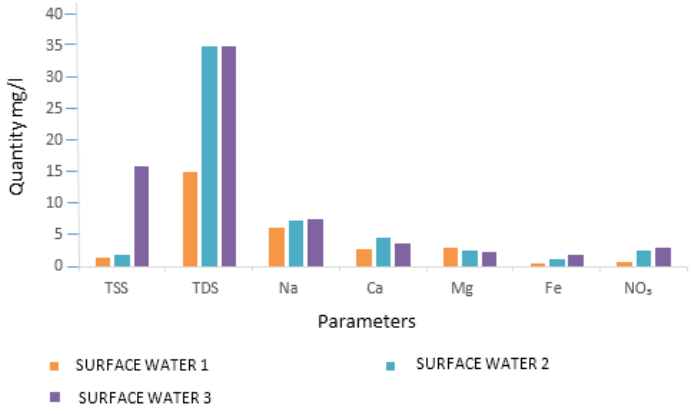

Figure 3. Water quality analysis from surface water sources in Mankessim during the wet season

Some chemical properties of soils sampled in dry and wet seasons from farms using surface water sources for irrigation (Mankessim)

The soil analysis was carried out on both the irrigated and non-irrigated farms for the wet and dry seasons as shown in Tab. 3. The pH of soils sampled from the irrigated farm in both the wet and dry seasons gave no significant differences which is 6.74 and 6.50 respectively which were both weak acidic soils. With the non-irrigated farms, there was significant difference between the wet and dry seasons which are 6.73 (slightly acidic) and 7.3 (neutral) respectively. Comparing the irrigated and non-irrigated soil analysis on pH, the wet season gave slight difference while that of the dry season gave significant difference. The electrical conductivity of the soil extract was extremely low with values lying between 0.14 and 0.51 dS/m for irrigated and non-irrigated farms respectively in the wet seasons. The dry season also had extremely low with values 0.09 and 0.34 for non-irrigated and irrigated farms respectively, which indicates the absence of a negative effect by (lack of danger) of dissolved solids in this soil.

Table 3. Chemical analysis of soil sampled in wet and dry season from farms which used surface water sourcesfor irrigation (Mankessim).

SEASON		DRY SEASON					WET SEASON	
		Irrigated area	Non-irrigated area	FAO VALUES			Irrigated area	Non-irrigated area
Location	Parameters	Mean	Mean	Normal	Moderate	Severe	Mean	Mean
	pH dS/m	6.5	7.3	5.5- 7.0 8.0	>9.5		6.74	6.73
	EC ms/l	0.34	0.09	0-2	4-15	>15	0.14	0.51

From the soil samples analyzed, the pH of the non-irrigated area for the dry season was recorded as 7.3 indicating that it was alkaline in nature while that of the irrigated area was within the acceptable FAO value which is 6.5. For the wet season, the values recorded for both the irrigated and non-irrigated areas were within the accepted FAO values and these were 6.74 and 6.73 respectively. These results indicate that the plant will not be affected negatively with regard to the pH of the soil after irrigating in both the dry and wet seasons. Also, the electrical conductivity values recorded in the soil were low and will have less influence on the salinity of the soil.

CONCLUSION

From the results of this study, the pH of the water in the dry season for all the surface water sources were slightly acidic and could be used for irrigation while that of the wet season were almost severe but could be adequately used for irrigation. However, continuous use of this water during the wet season could affect the system or equipment used for irrigation, uniformity, crop growth and yield. The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in the spray tube systems. The optimum pH will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but is often in the range 5.5 – 9.5. Extreme pH values can result from accidental spills, treatment breakdowns, and insufficiently cured cement mortar pipe linings. Also, the sodium absorption ratio values which influences the infiltration of water into the soil for the reach of plant root were all normal thus the plant root could have access to the irrigated water. The electrical conductivity level for all the water sources and soil parameters measured were low and thus could have less or no effect on the salinity of the water which could be detrimental to irrigation tubes and pipes. The soil samples for the wet season were slightly acidic and favorable for crop growth while those of the dry season were normal in terms of their acidity. This indicates that the water was favorable for irrigating crops within the catchment area and will not inhibit the irrigation system used.

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OCENA KVALITETA VODE ZA NAVODNJAVANJE I ODABRANI PARAMETRI ZEMLJIŠTA ZA MANKESSIM OBLAST, GANA

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Apstrakt: Navodnjavanje je postao veoma kritični faktor u postizanju određenog kvaliteta proizvodnje useva tokom cele godine. Cilj ovog istraživačkog rada bio je procena kvaliteta vode za navodnjavanje za određene parametre zemljišta za oblast navodnjavanja Mankessim (Gana), koja se koristi za navodnjavanje svih vrsta useva u ovoj oblasti i okolini.

Podaci za studiju prikupljeni su iz dve oblasti: uzoraka vode i zemljišta. Uzorci vode su prikupljeni iz tri različita izvora površinske vode u okviru oblasti za sušnu i za vlažnu sezonu. Sakupljeno je devet (9) različitih uzoraka za svaku sezonu, tri (3) uzorka za svaki izvor površinske vode.

Takođe, sakupljeno je šest (6) različitih uzoraka zemljišta za svaku sezonu. Uzorci zemljišta su prikupljeni sa navodnjavanog i nenavodnjavanog poljoprivrednog zemljišta.

Rezultati studije su pokazali da se izvori vode (površinski), nisu značajno razlikovali po osobinama jedni od drugih u poređenju sušnih i vlažnih sezona i da su njihove hemijske vrednosti bile u granicama prihvatljivim za navodnjavanje i biljnu proizvodnju.

Koncentracije vrednosti (Na, Ca, Mg, EC i TDS) bile su značajno unutar dozvoljenih granica kod upotrebe vode za useve.

Ključne reči: *Kvalitet vode za navodnjavanje, salinitet, ukupne rastvorene čvrste materije.*

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THE IMPORTANCE OF MONITORING THE REALIZATION OF INCOME AND COSTS IN THE MANAGEMENT AND BUSINESS OF AGRICULTURAL ENTERPRISES IN RELATION TO THE INTRODUCED FORMS OF INTERNAL-CONTROL MECHANISMS

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Summary: Monitoring the formation of total income and total costs is of great importance for the practical operation of a large number of agricultural enterprises. The actual improvement of business decision-making in agricultural enterprises can be connected with the introduced forms of internal control mechanisms in the processes of regular business in agricultural enterprises. This was the basis of the research in this study. For the purposes of this study, the authors performed two two-way ANOVA analyses, one for the purpose of obtaining real data on the movement of income, and the other for determining the results of the operations of agricultural enterprises in relation to the occurrence of total operating costs in the business period of one business year. In both cases, we obtained results indicating that the formation of income and expenses indicates the existence of significance at the level of $p<0.05$, for large and small agricultural enterprises and established forms of internal control mechanisms. In addition, the authors found that the highest total revenues, regardless of whether they are large or medium-sized enterprises, are achieved when internal control is implemented as a form of internal control mechanism, and the lowest revenues are achieved by large and medium-sized enterprises when internal audit is implemented as a form of internal control. Regarding costs, the results indicate that there is a statistically significant influence of one of the three forms of implemented control mechanisms on the occurrence of costs, while there is no influence of the size of the agricultural enterprise on the realization of costs in business.

Keywords: *management, realization of income, expenditure.*

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INTRODUCTION

Establishing monitoring of the formation of total income and total costs is of great importance for the practical operation of a large number of agricultural enterprises [1-4].

The actual improvement of the business decisions made by the top management in the business of agricultural enterprises can be connected with the introduced forms of internal control mechanisms [5-7] and that in the processes of regular business.

In order to be able to realistically monitor the realization of income in the business of agricultural enterprises, it is necessary to discover some form of legality in the behavior.

One of the ways to properly reveal the legality of observations related to the acquisition of income in business is to use one of the forms of establishing internal control mechanisms in the processes of regular business decision-making [8-11].

In addition, for the proper functioning and management of the business of agricultural enterprises, it is necessary to properly monitor the costs in their amount, the total amount of business expenses incurred during the period of business, etc. [12-15].

Such an observation is the basis for achieving successful operations of a large number of companies, which is of great importance for developing countries that want to achieve optimal operations in the long term [16-18].

DESCRIPTION OF THE METHODOLOGY IN MONITORING THE REALIZATION OF INCOMEAND COSTS OF AGRICULTURAL ENTERPRISES IN RELATION TO THE INTRODUCED FORMS OF INTERNAL-CONTROL MECHANISMS IN BUSINESS PROCESSES

The research was conducted in 139 agricultural enterprises in the period January-February 2023. For the purposes of research in the study, the authors observed 22 large and 117 small agricultural enterprises in relation to the realized income and expenses that were disclosed in the last business year, i.e. which were achieved on 31.12.2021, in relation to the introduced forms of internal control mechanisms.

The top management is guaranteed anonymity, as well as the fact that no general information about the company will be disclosed, which can connect the data obtained from the company's final accounts for the last business year with the name of the company.

The authors undertook to use the obtained data for scientific purposes and not to disclose the company's general information.

All amounts of income and expenses are put in a comparative relationship with the mechanism of the introduced form of internal-control form of business in the mentioned companies.

DETERMINATION OF DIFFERENCES OF ACHIEVED INCOME AND THE APPLICATION OF INTERNAL-CONTROL MECHANISMS IN THE BUSINESS OF AGRICULTURAL ENTERPRISES

Determining the differences in realized incomes and the application of internal control mechanisms in the operations of agricultural enterprises was the first part of the conducted research.

The obtained results are presented by the author in Table 1.

They reflect the processed data based on classic statistical processing through two-way ANOVA analysis, based on the realized income and the realized form of control introduced in the company's operations.

Table 1. Dependent variables revenue, tests of between-subject effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	207158652.422[a]	4	41431730.484	77.642	.000
Intercept	142768528.177	1	142768528.177	267.546	.000
form of enterprise	22443953.939	1	22443953.939	42.060	.000
Internal control mechanism	49596134.412	2	24798067.206	46.471	.000
Form of enterprise/internal control mechanism	13019634.774	2	6509817.387	12.199	.000
Error	145145135.132	129	533621.820		
Total	696267658.000	139			
Corrected Total	352303787.554	138			

Source: Authors' calculations

THE EXISTENCE OF DIFFERENCES IN REGARDS TO ACHIEVED COSTS AND THE APPLICATION OF INTERNAL-CONTROL MECHANISMS IN THE BUSINESS OF AGRICULTURAL ENTERPRISES

The existence and determination of differences in the amount of total realized costs in relation to the application of internal control mechanisms in the operations of agricultural enterprises represented the second part of the research.

They reflected the presentation of the processed data through classical statistical processing through two-way ANOVA analysis of costs in relation to the introduced forms of internal control mechanisms in the company's operations.

The obtained results are presented by the authors in Table 2.

Table 2. Dependent variables-expenses, tests of between-subject effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	82777652.749[a]	4	16555530.550	76.891	.000
Intercept	90732309.312	1	90732309.312	421.402	.000
Form of enterprise	645531.290	1	645531.290	2.998	.084
Internal control mechanism	34915406.380	2	17457703.190	81.082	.000
Form of enterprise/internal control mechanism	7468785.624	2	3734392.812	17.344	.000
Error	58564418.895	129	215310.364		
Total	312572561.000	139			
Corrected Total	141342071.644	138			

Source: Authors' calculations

DISCUSSION

Based on the presentation of the obtained results in Table 1, a presentation of the results of the research regarding the ratio of realized income and the form of introduced internal controls in the operations of agricultural enterprises is given. The obtained results of the two-way ANOVA analysis have values of f=42,060; f=46,471; f=12,199. In addition, Table 1 shows the existence of obtained values $p<0.005$.

The results presented in this way point to the existence of statistical significance between the form of introduced internal control mechanisms and the income generated by agricultural enterprises.

Apart from that, it can be pointed out that there is an influence of the size of the company, as well as the influence of the form of implemented internal control mechanisms and the interaction between the internal control mechanism and the size of the company. The highest total revenues, regardless of whether they are large or medium-sized enterprises, are achieved when internal control is implemented as a form of internal control mechanism, and the lowest revenues are achieved by large and medium-sized enterprises when internal audit is implemented as a form of internal control.

Based on the presentation of the obtained results in Table 2, a presentation of the research results regarding the relationship between the realized costs and the applied forms of internal controls introduced in the operations of agricultural enterprises is given. The obtained results of the two-way ANOVA analysis have values of f=2.998; f=81.082; f=17.344. In addition, Table 2 shows the existence of obtained values $p<0.005$.

The results presented in this way point to the existence of statistical significance between the form of introduced internal control mechanisms and the realization of costs in agricultural enterprises.

We emphasize that medium-sized agricultural enterprises have the most costs when internal control is implemented as an internal control mechanism.

Large enterprises have the highest costs when there is a combination of internal control, internal audit and financial management and control in the operations of agricultural enterprises.

The results indicate that there is a statistically significant influence of one of the three forms of implemented control mechanisms on the occurrence of costs, while there is no influence of the size of the agricultural enterprise on the realization of costs in business.

CONCLUSION

The author's research in the study shows that there is great importance that top management should devote to practical application in connection with the realization of income and expenses in the business of agricultural enterprises. The introduced form of internal control mechanisms affects the realization of both income and expenses in the processes of regular business in agricultural enterprises based on the obtained results, which are visible in Table 1-2. The first conclusion would be that the form of the introduced internal control mechanism can affect the different realization of both income and expenses because in both cases all three forms of control gave results where the obtained value was $p<0.005$, which points to the existence of statistical significance in the previously stated conclusion.

Another conclusion would be that the highest total revenues, regardless of whether they are large or medium-sized enterprises, are achieved when internal control is carried out as a form of internal control mechanism, and the lowest revenues are achieved by large and medium-sized enterprises when internal audit is carried out. as a form of internal control. The third conclusion would be that there is a statistically significant influence of one of the three forms of implemented control mechanisms on the occurrence of costs, while there is no influence of the size of the agricultural enterprise on the realization of costs in the operations of agricultural enterprises.

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ZNAČAJ PRAĆENJA OSTVARENJA PRIHODA I TROŠKOVA U UPRAVLJANJU I POSLOVANJU POLJOPRIVREDNIH PREDUZEĆA U ODNOSU NA UVEDENE OBLIKE INTERNO-KONTROLNIH MEHANIZAMA

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Sažetak: Praćenje formiranja ukupnih prihoda i ukupnih troškova od velikog je značaja za praktično poslovanje velikog broja poljoprivrednih preduzeća. Stvarno unapređenje poslovnog odlučivanja u poljoprivrednim preduzećima može se povezati sa uvedenim oblicima mehanizama interne kontrole u procesima redovnog poslovanja poljoprivrednih poduzeća. To je bila osnova istraživanja u ovoj studiji. Za potrebe ovog istraživanja autori su uradili dve dvosmerne ANOVA analize, jednu kako bi dobili stvarne podatke o kretanju prihoda, a drugu kako bi utvrdili rezultate poslovanja poljoprivrednih preduzeća u odnosu na formiranje ukupnih troškova poslovanja u poslovnom periodu od jedne poslovne godine. U oba slučaja dobili smo rezultate koji ukazuju da se formiranje prihoda i rashoda ostvaruje uz postojanje statističke značajnosti na nivou $p<0,05$, za velika i mala poljoprivredna preduzeća i uspostavljene oblike interno-kontrolnih mehanizama. Osim toga, autori su utvrdili da se najveći ukupni prihodi, bez obzira radi li se radi o velikim ili srednjim preduzećima, ostvaruju uvođenjem interne kontrole kao oblika uvedenog interno-kontrolnog mehanizma, a najniže prihode ostvaruju velika i srednja preduzeća, odnosno velika preduzeća kada je uspostavljena interna revizija kao oblik interne kontrole.

Što se tiče troškova, rezultati pokazuju da postoji statistički značajan uticaj jednog od tri oblika implementiranih kontrolnih mehanizama na nastanak troškova, kao i to da nepostoji uticaj veličine poljoprivrednog poduzeća na ostvarenje troškova u poslovanju.

***Ključne reči**: Menadžment, stvaranje prihoda, rashodi.*

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FABRICATED DEVICE TO MEASURE THE MECHANICAL PROPERTIES OF GRAINS

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Abstract: Physical and mechanical properties of food crops gain importance during design of threshing and shilling machine. In Egypt, Corn is emerging as the third most important crop after rice and wheat, and it has significance as a source of a large number of industrial products besides its use as human food and animal feed. Corn is the Third largest cereal produced in the world with a trend of rising production in Egypt. The normal area for Corn in Egypt was hectares with production about tones in the year 2016. Four method of Corn shelling namely shelling cob grain by hand, octagonal Corn Sheller, hand operated Corn Sheller and beating by stick method were carried for removing Corn kernel from the cob. As well as, the determination of mechanical properties go to improve and optimize of separation and cleaning machine. The current study, some physical and mechanical properties of corn seeds were determined such as the average length, width, thickness and arithmetic diameter. In the moisture 8.5 and 16.7 % d.b., the results showed that, the thousand seed mass increased from. The rupture force value ranged from 141.2 to 431.6 N for corn type TWC370 dent and SC white flint at 8.5 % moisture content respectively. The rupture force value ranged from 182.3 to 529.8 N for corn type TWC370 dent and SC white flint at 16.7 % moisture content respectively. Also, the rupture energy value ranged from 279.5 to 1093.8 J for corn type TWC370 dent and SC white flint at 8.5 % moisture content respectively. The rupture energy value ranged from 369.3 to 1189.8 J for corn type TWC370 dent and SC white flint at 16.7 % moisture content respectively. But there was no regular trend for rupture force on the grains width section with increasing the moisture content.

Key words*: Mechanical properties, and rupture energy of corn*

INTRODUCTION

Corn with the scientific name of *Zea* is a valuable crop in plants. Diversity, high compatibility and its vast nutritional value among the world made it the most important crop [7], [1], [2] and [3].

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Corn has been of importance in the life of people since 4500 years ago [15], it is one of the most powerful crops and the greatest means to capture and store free energy in the land comes into account.
Corn is also a versatile crop, allowing it to grow across a range of agro-ecological zones. Every part of Corn has economic value as the grain, leaves, main crop stalk, tassel and cob can all be used to produce a large variety of food and non-food products.

In our country, most of the farmers' shell corn by mainly three methods namely shelling cob grain by hand; hand operated corn Sheller and beating by stick method were carried for removing corn kernel from the cob. The Corn shelling was designed and built to improve the standards of living of people living in villages of developing countries. There are several electrical operated Corn shelling machines for mass shelling. Mostly farmers used to take their unshelled Corns to such industries were they get their final product that is shelled Corn and then they used to sell this product to the market. The problems of underdevelopment are particularly acute in the rural areas of countries, where the poorest people live and where agricultural underproduction and migration has most effect. This synopsis on the design and fabrication of motorize operated Corn shelling machine that will remove corn from corn kernel. In order to design equipment for the handling, conveying, separation, drying, storing and processing of corn seed, it is necessary to determine their mechanical and physical properties as a function of moisture content. This study was conducted to investigate some moisture dependent mechanical and physical properties of corn seed namely; rupture force, rupture energy, sphericity, one thousand seed mass, volume, surface area, bulk density, true density, porosity and static coefficient of friction against different materials.

MATERIAL AND METHODS

Design and theory of the prototype of seeds testing device

To determine the mechanical properties of seeds, the fabricated prototype tension and compression testing machine was manufactured and used; which was equipped with a 50 kg compression load cell and an integrator. The measurement accuracy was ± 0.1 N in force and 0.001 mm in deformation (Figure 1). The individual grain was loaded between two parallel steel pin and cap of the machine and compressed along with thickness until rupture occurred. This was denoted by a rupture point in the force deformation curve. The rupture point is a point on the force deformation curve at which the loaded specimen shows a visible or invisible failure in the form of breaks or cracks. This point is detected by a continuous decrease of the load in the force deformation diagram. While the rupture point was detected, the loading was stopped. These tests were carried out at the loading rate of 5 mm/min for two moisture levels [4] and [6]. The mechanical behavior of corn seeds was expressed in terms of ruptured force and energy required for the initial rupture. The fabricated prototype testing device consisting of two helical springs that fixed in the movable horizontal plat moved on the two vertical hollow circular pins.
The calibrated weight balance with an analog graduated scalar was fixed in the center of the movable horizontal plat in bottom ending and the top ending was fixed in the frame.
The indicator fixed on the movable plat and scale bare fixed on the fame to measure the deflection of the spring wire.

Energy Stored in Helical Springs of Circular Wire

We know that the springs are used for storing energy which is equal to the work done on it by some external load. Let W = Load applied on the spring, and δ = Deflection produced in the spring due to the load W.

Assuming that the load is applied gradually, the energy stored in a spring is, U= 0.5 W. δ. We have already discussed that the maximum shear stress induced in the spring wire as shown in equation 1,

$$\tau = K \times \frac{8\,W.D}{\pi\,d^3} \text{ or } W = \frac{\pi\,d^3.\tau}{8K.D} \qquad \text{.....[1]}$$

We know that deflection of the spring shown in equation 2,

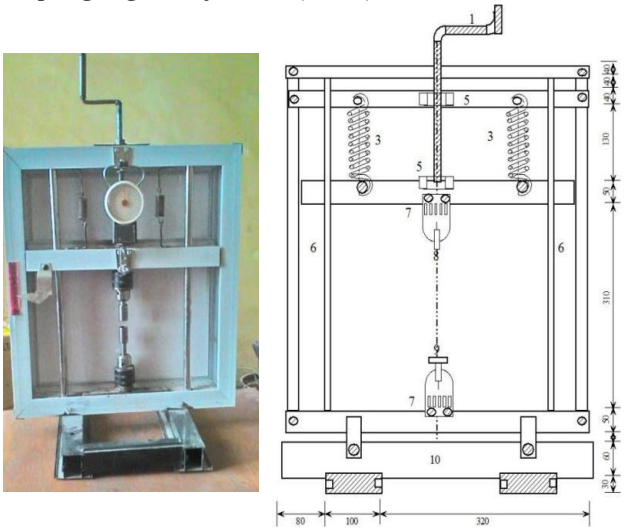
$$\tau = K \times \frac{8\,W.D}{\pi\,d^3} \text{ or } W = \frac{\pi\,d^3.\tau}{8K.D} \qquad \text{.....[2]}$$

Substituting the values of W and δ in equation **3**, we have

$$U = \frac{1}{2} \times \frac{\pi\,d^3.\tau}{8\,K.D} \times \frac{\pi\,\tau.D^2.n}{K.d.G}$$

$$= \frac{\tau^2}{4\,K^2.G}(\pi\,D.n)\left(\frac{\pi}{4} \times d^2\right) = \frac{\tau^2}{4\,K^2.G} \times V \qquad \text{..... [3]}$$

Where V = Volume of the spring wire = Length of spring wire × Cross-sectional area of spring wire. When a load (say P) falls on a spring through a height h, then the energy absorbed in a spring is given by $U = P\,(h + \delta) = 0.5\,W.\,\delta$



1-Rotating hand badly; 2- Graduated scaler 3-Two helical springs that fixed; 5- nuts; 4-the movable horizontal plat moved; 6-Two vertical hollow circular pins; 7- Screwcap; 8-frame.

Fig. 1. The construction diagram for fabricated mechanical properties of seeds testing device

The corn seeds (Figure 2), used in this research, are one of the prevalent varieties in. The initial moisture content of the samples was 14.2 % d.b. and was determined by oven drying at 103 ± 1°C for 72 h [4]. Equation (4) was used to determine the mass of the added water. The sample was kept in a cold place for 104 h to reach to the proper uniform moisture content [22].

$$W_a = W_t \frac{(M_f - M_i)}{(100 - M_f)} \qquad \text{..... [4]}$$

Where: Wa = Mass of water added, g.
Wt = Total grain mass,g.
Mi = Initial moisture content,%.
Mf = Final moisture content,%.

The moisture content (w.b.,%) of grains were determined by oven method. About five grams of wheat were placed in a shallow aluminum dish and dried for 72 hours at 130°. At the end of this time the constant mass showed that all moisture was driven off shown in equation 5.

$$M.C._{w.b.} = \frac{W_i - W_d}{W_i} \times 100 \qquad \text{..... .....[5]}$$

Where:
M w.b. = Moisture content, wet basis, %.
Wi = Initial mass of sample, g.
Wd = Dried mass of sample, g.

The samples of the desired moisture contents were prepared by adding the amount of distilled water as calculated from the equation 5 [7]: All the physical and mechanical properties of the seeds were determined at two moisture contents 8.5 and 16.7 % d.b.; with three replications for each moisture content. The length, width, thickness and mass of corn seeds were measured on randomly selected 100 corn seeds under two moisture content conditions. The length, width and thickness of materials were measured using a digital caliper with an accuracy of 0.01 mm. The average diameter of seeds was calculated by using the arithmetic mean and geometric mean of the three axial dimensions by using the digital caliper as shown in figure 2. The arithmetic mean diameter (Da) and geometric mean diameter (Dg) of the seeds were calculated by using the following equations [15]: The sphericity of seeds was calculated by using the following equations [15]: The one thousand grains mass was determined using a digital electronic balance having an accuracy of 0.001 g. To evaluate the one thousand grain mass, 100 grains were randomly selected from the bulk samples and then averaged. The surface area and volume of corn seeds were found by analogy with a sphere of the same geometric mean diameter, using the following equations [17 and 12] The geometric mean (Dgm), and equivalent diameter (Dem), in mm was calculated by the following Equation (6 and 7) respectively [15].

$$D_{gm} = (LWT)^{1/3} \quad mm \qquad \text{... [6]} \qquad D_{em} = \left[L \frac{(W+T)^2}{4} \right]^{\frac{1}{3}} mm \qquad \text{.....} \qquad \text{.[7]}$$

The arithmetic mean diameter in equation (8), of the grain was expressed by [21] using the following relationship:

$$D_{am} = \frac{L+W+T}{3} mm \quad .[8]$$

The Percentage of spherically (S) defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain. It was determined by using the following Equation 9 [15].

$$S = \frac{(LWT)^{1/3}}{L} \quad \% \quad \text{…….. [9]}$$

The bulk density of grain was calculated as the ratio of the bulk mass and the volume of the container as shown in equation (10).

$$\beta = m/v \quad \text{……..... [10]}$$

Where: β: is the bulk density of the grain, kg/m^3
m: mass of wheat grain in kg,
v: volume of the container in m^3

The true density is the ratio of the mass sample of grain to its pure volume. The pure volume was estimated by putting the weighted sample in a measuring flask (250 ml) filled to its a half with water and estimate the variance of water volume. It was determined by the toluene displacement method shown in equation 11 [15].

$$\rho t = m/Vs \quad [11]$$

Where: ρt: True density of the grains, kg/m^3,
m: Mass of wheat grain in kg,
Vs: Variance of water volume m^3.

The angle between the cone surface and the horizontal plan was recorded to represent repose angle of grain. Assuming that the horizontal base length of the cone (x) and the cone height (L), then the repose angle can be calculated using the following simple relations 12:

$$\theta = \tan^{-1}\frac{L}{0.5X} \quad \text{…….} \quad \text{……. [12]}$$

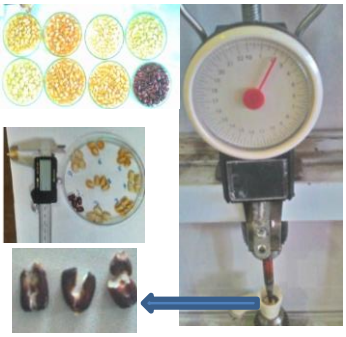


Fig.2. Display the measuring of the axial dimensions by using the digital caliper and forces in fabricated mechanical testing device

The different type of corn TWC370 dent, Universal 650N, TWC 360 yellow dent, SC white dent132, TWC 368 yellow flint, SC white Flint 178, SC white Flint and SC yellow dent were used and evaluated in fabricated device.

Bulk and true density

The average bulk density of the corn seeds was determined using the standard test weight procedure reported by [11], [10] and [20]by filling a container of 500 ml with the seed from a height of 150 mm at a constant rate and then weighing the content. The average true density was determined using the toluene displacement method. The volume of toluene (C7H8) displaced was found by immersing a weighed quantity of dent corn seeds in the toluene [17] and [8]. The porosity was calculated from the following equation [15].

The angle of repose

The angle of repose is the angle compared to the horizontal at which the material will stand when piled. This was determined by using the apparatus; consisting of a plywood box of 140 × 160 × 35 mm and two plates: fixed and adjustable. The box was filled with the sample, and then the adjustable plate was inclined gradually allowing the grains to follow and assume a natural slope, this was measured as emptying angle of repose [22] and [9].

The static coefficients of friction

The static coefficient of friction of seeds against three different surfaces, namely; plywood, compressed plastic and galvanized iron sheet were determined using a cylinder of diameter 75 mm diameter and 50 mm depth, filled with seeds. With the cylinder resting on the surface, the surface was raised gradually until the filled cylinder just started to slide down [16] and [9].). The coefficient of friction was calculated from the following equation:

$$\mu = \tan \alpha$$

Where W = Equivalent static load *i.e*. the gradually applied load which shall produce the same effect as by the falling load P, and δ = Deflection produced in the spring.

RESULTS AND DISCUSSION

The result focused on the following items:

Bulk and true density: The corn type TWC370 dent has low bulk density and true density compared with corn type Universal 650N and SC white Flint 178, SC as shown in table 1 and 2. The bulk density was 690 $kg.m^{-3}$and 740 $kg.m^{-3}$for corn type TWC370 dent at 8.5 % and 16.7% moisture content respectively. In table 2, the bulk density was 731 kg m^3 and 791 $kg.m^{-3}$for corn type Universal 650N at 8.5 % and 16.7% moisture content respectively. The true density was 1098 g cm^{-3} and 1108 g cm^{-3} for corn type TWC370 dent at 8.5 % and 16.7% moisture content respectively.

Table 2 presented the true density 1242 $kg.m^{-3}$and 1302 $kg.m^{-3}$for corn type Universal 650N at 8.5 % and 16.7% moisture content respectively.

Angle of repose: Table showed the variation of the static angle of repose with seed moisture content increase from 8.5 to 16.7%. The values were found to increase from 53o to 59°. The increasing trend of angle of repose with moisture content occurs because the surface layer of moisture surrounding the particle holds the aggregate of grain together by the surface tension [15].
The angle of repose was 53º and 55º for corn type TWC370 dent at 8.5 % and 16.7% moisture content respectively. The angle of repose was 56º and 59º for corn type Universal 650N at 8.5 % and 16.7% moisture content respectively.

The static coefficient of friction: The static coefficient of friction of corn seeds on two surfaces (plastic and galvanized iron) against moisture content in the range of 8.5 to 16.7% d.b. are presented in table 1 and table 2.
The static coefficient of friction was 0.52 and 0.58 for corn type TWC370 dent at 8.5 % and 16.7% moisture content on galvanized iron sheet surface respectively. The static coefficient of friction was 0.58 and 0.69 for corn type Universal 650N at 8.5 % and 16.7% moisture content on galvanized iron sheet surface respectively.
The static coefficient of friction was 0.56 and 0.67 for corn type TWC370 dent at 8.5 % and 16.7% moisture content on plastic surface respectively. The static coefficient of friction was 0.61 and 0.73 for corn type Universal 650N at 8.5 % and 16.7% moisture content on plastic sheet surface respectively.
It was observed that, the static coefficient of friction increased linearly with increase in moisture content for all the surfaces. The maximum value of 0.73 was obtained on the surface of compressed plastic and the minimum value of 0.52 was on the surface of galvanized iron sheet. Similar findings were reported for pumpkin seeds [13]; karingda seeds [21].; millet [5].; okra seed [18].
Seed dimensions: The mean values and standard errors of the axial dimensions of the corn seeds at different two moisture contents are presented in table 3 and table 4. The three axial dimensions and average diameters, increased with an increase in moisture content from 8.5 to 16.7% d.b. Each principal dimension appeared to be linearly dependent on the moisture content. The corn type TWC370 dent has low diameter and surface area compared with corn type Universal 650N and SC white Flint 178, SC. The geometrical diameters were 8.26 mm and 8.48 mm for corn type TWC370 dent at 8.5 % and 16.7% moisture content respectively.
The geometrical diameter was 9.02 mm and 9.24 mm for corn type Universal 650N at 8.5 % and 16.7% moisture content respectively. The surface area was 214,16 mm^2 and 225.6 mm^2 for corn type TWC370 dent at 8.5 % and 16.7% moisture content respectively. The surface area was 257.67 mm^2 and 267.1 mm^2 for corn type Universal 650N at 8.5 % and 16.7% moisture content respectively.

Rupture force and rupture energy: In the current research, in order to measure rupture force and rupture energy, the device which is shown in Figure 1 was used. The table 5 and table 6 showed that, the rupture force on thickness sections decreased with moisture content in the moisture range of 8.5 to 16.7% d.b.
The rupture force value ranged from 141.2 to 431.6 N for corn type TWC370 dent and SC white flint at 8.5 % moisture content respectively. The rupture force value ranged from 182.3 to 529.8 N for corn type TWC370 dent and SC white flint at 16.7 % moisture content respectively.
Also, the rupture energy value ranged from 279.5 to 1093.8 J for corn type

TWC370 dent and SC white flint at 8.5 % moisture content respectively.
The rupture energy value ranged from 369.3 to 1189.8 J for corn type TWC370 dent and SC white flint at 16.7 % moisture content respectively. But there was no regular trend for rupture force on the grains width section with increasing the moisture content.

Table (1): present the average values of mechanical properties for the different eight hybrid corn at moisture content 8.5 % d.b.

Type of corn	Bulk density, kg/cm^3	True density, kg/cm^3	Angle of repose, degree	Static coeff. of friction	
				Glva.	plastic
TWC370 dent	690	1098	53	0.52	0.63
Universal 650N	738	1242	56	0.58	0.69
TWC 360 yellow dent	697	1159	53	0.53	0.61
SC white dent132	689	1098	52	0.54	0.61
TWC 368 yellow flint	711	1121	54	0.55	0.62
SC white Flint 178	732	1238	55	0.56	0.64
SC white Flint	731	1232	55	0.56	0.63
SC yellow dent	692	1096	53	0.53	0.65

Table (2) present the average values of mechanical properties for the different eight hybrid corn at moisture content 16.7 % d.b.

Type of corn	Bulk density, kg/cm^3	True density, kg/cm^3	Angle of repose, degree	Static coeff. of friction	
				Glva	plastic
TWC370 dent	740	1128	55	0.56	0.67
Universal 650N	784	1289	57	0.61	0.73
TWC 360 yellow dent	756	1209	55	0.57	0.70
SC white dent132	761	1118	54	0.58	0.69
TWC 368 yellow flint	782	1211	57	0.62	0.72
SC white Flint 178	779	1298	56	0.63	0.72
SC white Flint	791	1302	59	0.67	0.71
SC yellow dent	742	1126	55	0.56	0.72

Table: (3) present the geometric values of the different eight hybrid corn at moisture content 8.5 % db.

Type of hybrid corn	dimension, mm			Athematic diam.,	Geometric dia.	surface area,
	L	w	t	mm	mm	mm^2
TWC370 dent	12.73	7.50	4.54	20.82	8.26	214.16
Universal 650N	13.44	9.98	3.64	22.09	9.02	255.57
TWC 360 yellow dent	12.50	8.29	4.51	21.60	8.43	223.27
SC white dent132	13.09	9.31	4.35	23.02	8.92	249.61
TWC 368 yellow flint	12.90	8.44	3.91	20.62	8.42	222.55
SC white Flint 178	12.26	9.92	4.43	23.20	8.87	247.23
SC white Flint	12.34	8.13	3.91	19.81	8.127	207.4
SC yellow dent	12.34	8.18	3.97	20.03	8.17	209.38

Table: (4) present the geometric values of the different eight hybrid corn at moisture content 16.7 % db.

Type of hybrid corn	dimension, mm			Athematic diam.,	Geometric dia.	surface area,
	l	W	T	mm	mm	mm^2
TWC370 dent	12.96	7.72	4.75	21.80	8.477	225.6
Universal 650N	13.88	10.3	3.54	22.50	9.240	268.1
TWC 360 yellow dent	12.37	8.47	4.31	21.25	8.383	220.7
SC white dent132	13.09	9.39	4.39	23.23	8.957	251.9
TWC 368 yellow flint	12.11	8.28	3.99	20.00	8.127	207.4
SC white Flint 178	11.96	10.6	4.42	23.67	8.993	254.0
SC white Flint	12.51	10.29	4.27	23.44	9.02	255.85
SC yellow dent	12.34	8.13	3.91	19.81	8.127	207.4

Table: (5) Present the average values of mechanical properties for the different eight hybrid corn at moisture content 8.5 % db

Type of corn	Rupture force kg	Rupture force N	stress, $kN.mm^{-2}$	Energy absorbed,	weight of 100 seeds
TWC370 dent	44.0	431.6	0.95	1093.8	32.78
Universal 650N	26.2	257.0	0.47	693.5	42.24
TWC 360 yellow dent	22.8	223.6	0.51	565.1	43.77
SC white dent132	37.0	382.4	0.76	932.8	37.66
TWC 368 yellow flint	21.8	217.0	0.52	495.3	40.62
SC white Flint 178	18.2	188.2	0.34	435.0	46.25
SC white Flint	14.4	141.2	0.32	279.5	41.40
SC yellow dent	21.6	221.8	0.51	453.6	34.08

Table: (6) present the average values of mechanical properties for the different eight hybrid corn at moisture content 16.7 % db.

Type of corn	Rupture force kg	Rupture force N	stress, $kN.mm^{-2}$	Energy absor.,J	weight of 1000 grains
TWC370 dent	54.0	529.8	1.2	1189.8	327.8
Universal 650N	31.4	307.4	0.6	783.5	422.4
TWC 360 yellow dent	27.4	268.2	0.6	655.1	437.7
SC white dent132	42.6	418.6	0.8	1022.8	376.6
TWC 368 yellow flint	24.0	235.4	0.5	575.3	406.2
SC white Flint 178	21.4	196.4	0.4	545.4	462.5
SC white Flint	18.6	182.4	0.4	369.3	414.0
SC yellow dent	22.6	222.4	0.5	533.9	340.8

CONCLUSIONS

The following conclusions are drawn from this investigation on mechanical and physical properties of corn grains for moisture content range of 8.5 to 16.7 % d.b.:
Mi, initial moisture content of sample; bulk density (kg m^{-3}); true density (kg m^{-3}); FR, rupture force; ER, rupture energy.
The corn type TWC370 dent has low bulk density and true density compared with corn type Universal 650N and SC white Flint 178, SC. The values were found to increase from 53º to 59°.
The increasing trend of angle of repose with moisture content occurs because the surface layer of moisture surrounding the particle holds the aggregate of grain together by the surface tension. The static coefficient of friction was 0.56 and 0.67 for corn type TWC370 dent at 8.5 % and 16.7% moisture content on plastic surface respectively. The static coefficient of friction was 0.61 and 0.73 for corn type Universal 650N at 8.5 % and 16.7% moisture content on plastic sheet surface respectively. The corn type TWC370 dent has low diameter and surface area compared with corn type Universal 650N and SC white Flint 178, SC. The geometrical diameters were 8.26 mm and 8.48 mm for corn type TWC370 dent at 8.5 % and 16.7% moisture content respectively.

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PRIMENA UREĐAJA ZA ODREĐIVANJE MEHANIČKIH OSOBINA ZRNA

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Apstrakt: Fizičko-mehaničke osobine prehrambenih poljoprivrednih useva dobijaju na značaju pri projektovanju mašine za ubiranje i odvajanje zrna. U Egiptu se kukuruz pojavljuje kao treća najvažnija kultura posle pirinča i pšenice i ima značaj kao izvor velikog broja industrijskih proizvoda pored upotrebe za ljudsku ishranu i stočnu hranu.
Kukuruz je treća po veličini žitarica u Svetu sa trendom rasta proizvodnje u Egiptu.
Uobičajena mera za produkciju kukuruza u Egiptu bila je proizvodnja oko tone po hektaru u 2016. godini.
Četiri metode pripreme zrna kukuruza: klasično ručno odvajanje zrna od klipa; osmougaoni rotacioni uređaj za odvajanje zrna od klipa; ručni uređaj za odvajanje zrna od klipa sa udarom, su primenjene za odvajanje zrna od klipa kukuruza.
Takođe, određivanje mehaničkih svojstava zrna, podrazumeva primenu poboljšane metode i optimizaciju mašine za separaciju i čišćenje zrna .
U ovoj studiji utvrđena su fizička i mehanička svojstva zrna kukuruza: prosečna dužina, širina, debljina i aritmetički prečnik. Kod od 8,5 i 16,7 % sadržaja vlage, rezultati su pokazali, da je masa hiljadu zrna, u porastu.
Vrednost sile loma zrna kretala se u rasponu od 141,2 do 431,6 N za kukuruz tipa TWC370 i SC belog zrna pri 8,5 % sadržaja vlage respektivno.
Vrednost sile lomljenja kretala se u rasponu od 182,3 do 529,8N za kukuruz tipa TWC370 i SC belo zrno sa 16,7 % sadržaja vlage respektivno.
Takođe, vrednost energije pucanja kretala se u rasponu od 279,5 do 1093,8 J za kukuruz tipa TWC370 i SC belo zrno pri 8,5 % sadržaja vlage respektivno.

Vrednost energije pucanja zrna kretala se u rasponu od 369,3 do 1189,8 J za kukuruz tipa TWC370 i SC belo zrno, pri 16,7 % sadržaja vlage respektivno.
Nije primećen-registrovan redovni trend promene sile kidanja na preseku širine zrna sa povećanjem sadržaja vlage.

Ključne reči: *Mehanička svojstva, energija lomljenja zrna kukuruza*

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