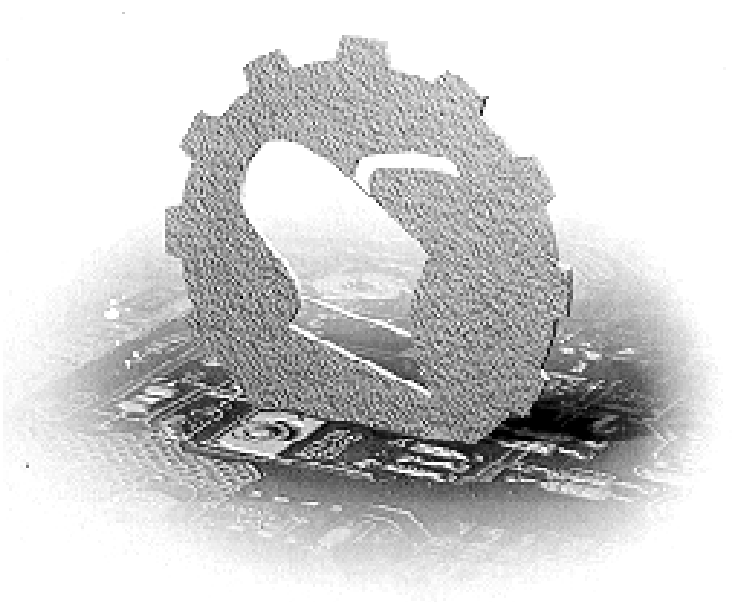
Print ISSN 0554-5587
On line eISSN 2406-1123
UDK 631 (059)

ПОЉОПРИВРЕДНА ТЕХНИКА

AGRICULTURAL ENGINEERING

НАУЧНИ ЧАСОПИС
SCIENTIFIC JOURNAL



УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ
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Година XLVII, Број 1., 2022.
Year XLVII, No.1., 2022.

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INSTITUTE OF AGRICULTURAL ENGINEERING

WEB адреса ***(WEB Address)***
www.jageng.agrif.bg.ac.rs

Техничка припрема *(Technical editor)*
Проф. др Коста Глигоревић, Пољопривредни факултет, 11080 Земун-Београд, Р.Србија

Лектура и коректура: *(Proofreader)*
Проф. др Иван Златановић, Машински факултет , 11120 Београд 35, Р.Србија

Превод: *(Translation)*
Проф. др Иван Златановић (Енглески језик), Машински факултет , 11120 Београд 35, Р.Србија
Проф. др Андреј Стојановић (Руски језик), Пољопривредни факултет, 11080 Земун-Београд, Р.Србија

Штампа *(Printed by)*
Пољопривредни факултет , 11080 Земун-Београд, Р.Србија
Часопис излази четири пута годишње

Тираж *(Circulation)*
200 примерака
Дистрибуција примерака часописа Пољопривредна техника за заинтересоване је бесплатна .

Радови објављени у часопису индексирани су у базама *(Abstracting and Indexing)*:
AGRIS (International Information System for the Agricultural Science and Technology)
SCIndeks (Serbian Citation Index)
NAAS (National Academy of Agricultural Sciences - India)
ScienceMediaCentre
ArgosBiotech
CiteFactor (International Academic Scientific Journals)
J4F (Journals for Free).
AgroSpace, Faculty of Agriculture, University of Belgrade, Republic of Serbia

Издавање часописа помогло *(Publication supported by)*
Министарство просвете, науке и технолошког развоја Републике Србије
Према одлукама Министра просвете, науке и технолошког развоја: 451-03-684/2020-14
и 451-03-1210/2020-14/2 .

На основу мишљења Министарства за науку и технологију Републике Србије према решењу бр. 413-00-606/96-01 од 24. 12. 1996. године, научни часопис Пољопривредна техника је ослобођен плаћања пореза на промет робе на мало.

S A D R Ž A J

C O N T E N T S

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLVII
Broj 1, 2022.
Strane: 1 – 14

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLVII
No. 1, 2022.
pp: 1 – 14

UDK: 631.3:621.8.036.

Pregledni rad
Review article
doi: 10.5937/PoljTeh2201001P

AUTOMATSKO UPRAVLJANJE SISTEMIMA ZA NAVODNJAVANJE

Ponjičan O.[*1], Učur S.[2], Vučinić Ž.[3], Samardžić B.[4], Sedlar A.[1], Turan J.[1], Višacki V.[1], Vasić F.[1]

[1]Univerzitet u Novom Sadu, Poljoprivredni fakutet, Departman za poljoprivrednu tehniku, Trg Dositeja Obradovića 8, Novi Sad, R. Srbija
[2]Agroaqua d.o.o, Arona Zagorice 1, Veternik, R.Srbija
[3]Hidrozavod DTD, Petra Drapšina 56, Novi Sad, R.Srbija
[4]Agrosavet-Irrigation d.o.o, Vladimira Garjanskog 2, Vrbas, R. Srbija

Sažetak: Autonomni sistemi za navodnjavanje razvijeni su kako bi se optimizovala upotreba vode prilikom poljoprivredne proizvodnje i smanjio utrošak ljudskog rada. Navedeni sistemi treba da imaju mogućnost daljinske kontrole i upravljanja u svakom trenutku od strane poljoprivrednog proizvođača. Korišćenje senzora i mogućnosti daljinskog očitavanja potrebni su za prikupljanje podataka u realnom vremenu o stanju useva, fazi razvoja i ostalim parametrima koji se odnose na vremenske prilike, useve i zemljište kako bi podržali inteligentne i efikasne sisteme upravljanja navodnjavanjem. Senzori daljinski komuniciraju sa centralnom upravljačkom jedinicom i glavnom kontrolnom jedinicom koja procesuira veliki broj ulaznih parametara, i korićenjem složenih algoritama generiše izlaznu upravljačku funkciju: kada, gde i koliko navodnjavati. Operator takođe mora da ima mogućnost da u realnom vremenu pristupi i upravlja mašinom za navodnjavanje sa bilo kog mesta i u bilo koje vreme. Daljinska bezžična komunikacija može da se odvija na više načina: Wi-Fi, radio i GSM/GPRS. Izbor komunikacionog sistema zavisi od topografije i troškova.

[*]Corresponding Author. E-mail: ondrej.ponjican@polj.uns.ac.rs

Neophodan je dalji razvoj aplikacija bežičnih senzora u poljoprivredi radi povećanja efikasnosti, produktivnosti i profitabilnosti svake tehnološke operacije u poljoprivredi, a time i poljoprivredne proizvodnje u celini.

Ključne reči: *automatsko upravljanje, daljinska kontrola i upravljanje, precizno navodnjavanje, zaštita životne sredine.*

UVOD

Pred poljoprivredu se postavljaju strateški zahtevi za proizvodnju sve veće količine hrane, a pri tome se obradive površine smanjuju i javljaju se sve nepovoljniji uslovi za proizvodnju, koji se prvenstveno ogledaju u nedovoljnoj količini padavima [1]. Voda za navodnjavanje ima strateški značaj i nedostatak vode za navodnjavanje jedan je od ograničavajućih faktora povećanja prinosa. Navodnjavanjem dopunjava se količina prirodnih padavina, kada je ona prema zahtevima gajenih biljaka u deficitu. Procenjuje se da se 40% slatke vode koja se koristi za navodnjavanje u poljoprivrednoj proizvodnji u zemljama u razvoju gubi ili isparavanjem, izlivanjem ili apsorpcijom dubokih slojeva zemljišta izvan dometa korenoog sistema gajenih biljaka [2]. Poljoprivreda je glavni korisnik slatke vode i troši približno 70% slatke vode, tj. na globalnom nivou, svake godine se iskoristi od 1500 od 2500 milijardi m^3 vode [3]. Klimatske promene kojih smo svedoci izazvaće dodatni pritisak na povećanje potrošnje vodnih resursa za 70–90% do 2050. godine [4].

Osnovne metode navodnjavanja su: plavljenjem, veštačkom kišom i kapanjem (površinsko postavljanje laterala, podpovršinsko i na veću dubinu-subirigacijom), [5]. Ujednačenost aplikacije vode po površini i efikasnost korišćenja vode je različita u zavisnosti od primenjene metode navodnjavanja [6]. Navodnjavanje veštačkom kišom (rasprskivačima) koji su postavljni stacionarno ili su pokretni, znatno je efikasnije od površinskog navodnjavanja. Međutim u vrućim i vetrovitim oblastima navodnjavanje veštačkom kišom može imati značajne gubitke vode usled isparavanja i odnošenja vetrom. Neadekvatno održavanje sistema usled istrošenosti rasprskivača, ili curenja na spojnim mestima, izaziva veliku neujednačenost raspodele vode i efikasnost celog sistema. Navodnjavanje kapanjem karakteriše učestalije navodnjavanje odgovarajućim normama uz vlaženje samo dela parcele, usled čega dolazi do značajnog povećanja prinosa i povećanje efikasnosti korišćenja vode u odnosu na površinsko navodnjavanje. Ulažu se veliki napori da se što više površina navodnjava veštačkom kišom i kapanjem. Izbor metoda navodnjavanja zavisi od karakteristika zemljišta, dostupnosti vode i klimatskih uslova, kao i od vrste useva, obučenosti korisnika, kapitalnih i operativnih troškova i dostupnosti infrastructure.

Tabela 1. Efikasnost aplikacije u zavisnosti od metoda navodnjavanja, [7].
Table 1 Application efficiency depending on irrigation method, [7].

Metod navodnjavanja Irrigation method	Efikasnost aplikacije (%) Application efficiency (%)
Površinsko navodnjavanje Surface irrigation	50–80
Navodnjavanje veštačkom kišom (rasprskivačima) Sprinkler irrigation	60–85
Navodnjavanje kapanjem Drip irrigation	80–90

Ne postoji idealan metod navodnjavanja koji bi bio odgovarajući za sve vremenske prilike, tipove zemljišta i različite gajene kulture [8].

Upotrebom senzora kada se navodnjavanje izvodi metodom kap po kap i rasprskivačima, efikasnost primene može da dostigne 80 do 90% u odnosu na 40 do 45% korišćenjem metoda površinskog navodnjavanja [9]. Primenom senzora vlažnosti zemljišta, u svojim istraživanjima [10] ostvarili su uštedu vode za navodnjavanje od 16%.

Navodnjavane površine i značaj navodnjavanja

U Republici Srbiji u toku 2012. godine navodnjavano je 99773 ha, što predstavlja svega 2,9% korišćenog poljoprivrednog zemljišta [11]. U toku 2018. godine ukupno je navodnjavano 176569 ha što iznosi 4,27% korišćenog poljoprivrednog zemljišta, koje obuhvata oranice i bašte, [12]. Navodnjavane površine u AP Vojvodini u toku 2012. godine iznosile su 58251 ha, što predstavlja svega 3,6% od ukupno korišćenog poljoprivrednog zemljišta [11], a do početka 2020. godine navodnjavane površine u AP Vojvodini dostigle su približno 100000 ha, (interna dokumentacija JVP Vode Vojvodine), što predstavlja povećanje za oko 70% za prethodnih 7 godina. Evidentno je povećanje, ali treba još intenzivnije raditi na stvaranju preduslova za povećanje navodnjavnih površina. Prilikom uvođenja navodnjavanja, na prvom mestu treba obezbediti dovoljne količine vode za navodnjavanje. Sa ekološkog i moralnog stanovišta, za navodjavanje, prvenstveno treba koristiti površinske vode iz reka i kanala. Trenutno društvena zajednica ulaže velike napore u izgradnju i revitalizaciju kanalske mreže. Uvođenjem navodnjavanja pored toga što se postižu stabilniji i viši prinosi visokog kvaliteta, pruža se i mogućnost pouzdanog planiranja proizvodnje, što je od presudnog značaja za razvoj poljoprivrednog preduzeća.

Metode daljinske komunikacije

Osnovni uslov za uvođenje daljinskog, automatskog upravljanja na sistemima za navodnjavanje predstavlja dobra komunikacija između elemenata sistema. Povezivanje senzora i centralne upravljačke jedinice može da se izvede pomoću provodnika ili bezžično. Daljinski, bezžični pristup i komunikacija može se ostvariti primenom opreme koja koristi GSM i GPRS mobilne telefonije, RF radio, satelitski radio, kao i hibridne sisteme zasnovane na internet konekciji sa računarima kombinovani sa bezžičnim RF sistemima.

Povezivanje terenske senzorske stanice sa baznom stanicom pomoću provodnika nije praktično zbog troškova, rada i održavanja, posebno ako su rastojanja veća od 10 m [2]. Žice se mogu oštetiti prilikom rada poljoprivredne mehanizacije i od strane životinja, a postoji i opasnost od groma. Korišćenjem bežičnih sistema za prenos podataka izbegavaju se mnogi od ovih problema, postiže se dinamička mobilnost i lako premeštanje i zamena terenskih senzorskih stanica. Za povezivanje većeg broja prostorno raspoređenih terenskih senzorskih stanica sa baznom stanicom može da se kristi Bluetooth, Wi-Fi, ili radio signal čiji domet može biti i do 10 km. Korišćenje interneta (GPRS) za povezivanje većeg broja prostorno raspoređenih terenskih senzorskih stanica ekonomski nije isplativo. Tehnologija radio frekvencija je široko prihvaćena i pruža mogućnosti za primenu bežične signalne komunikacije unutar poljoprivrednih sistema (sl. 1).

Slika 1. Antena za daljinsko upravljanje korišćenjem radio signala na mašini za navodnjavanje.
Figure 1. Antenna for remote control using a radio signal on a center-pivot irrigation machine.

Dva bežična protokola: Bluetooth i ZigBee dizajnirani su za radio-frekvencijske (RF) aplikacije za mobilne aplikacije koje imaju relativno malu brzinu prenosa podataka, dug vek trajanja baterije i dobru mrežnu sigurnost [13]. Bluetooth je brži i skuplji standard od ZigBee-a i koristi tehnologiju modulacije šireg spektra. Bluetooth bežična može da se iskoristi za povezivanje senzora, i radi kontrole i podešavanja poljoprivrednih sistema [14]. Bluetooth radio konekcija u različitim poljoprivrednim okruženjima, može da ostavari domet do 44 m, pri čemu optimalna visina antene treba da bude 1,4 m [15]. ZigBee ima manje potrebe za napajanjem od Bluetooth-a, ali takođe može efikasno da prenosi informacije na manju udaljenost (npr. 30 m). U novije vreme dostupni su poboljšani Bluetooth predajnici koji mogu preneti podatke na razdaljinu do 1 km.

Wi-Fi predstavlja familiju protokola koji se koriste za međusobno lokalno bezžično povezivanje uređaja, ako i za pristup internetu. Različite verzije Wi-Fi sa različitim radio tehnologijama, koje rade u okviru različitih radio opsega, mogu postići različitie brzine i domete. Prepreke u značajnoj meri smanjuju domet.

Pristupna tačka (hot spot) često ima domet od oko 20 m u zatvorenom, dok poboljšane pristupne tačke na otvorenom mogu imati domet i do 150 m.

LoRa (Long Range) je protokol širokopojasne mreže male snage (LPVAN), koristi dozvoljene (bez licencne) opsege radio frekvencija kao što su 433 MHz, 868 MHz (Evropa), 915 MHz (Australija i Severna Amerika), 865 MHz do 867 MHz (Indija) i 923 MHz (Azija). LoRa omogućava prenos podataka na velika rastojanja (više od 10 km u ruralnim oblastima) uz malu potrošnju energije.

Automatska kontrola sistema za navodnjavanje putem GSM, korišćenjem android mobilnog telefona bazirana je na korišćenju GSM modula RS-232, [16]. Sistem može kontinuirano daljinski kontrolisati nivo vode (senzor nivoa vode), temperaturu i vlažnost zemljišta.

Putem SMS-a sa GSM android mobilnim telefonom moguće je i upravljanje elektromagnetnim ventilima sa kontrolerima za uključivanje ili isključivanje pumpe za navodnjavanje. Ovakav sistem je jeftin i efikasan, uz manju potrošnju energije. Sistemi takođe mogu da koriste GSM mrežu za slanje poruka upozorenja [17].

GPRS **(**General Packet Radio Service) je usluga koja je dostupna korisnicima mobilnih telefona i omogućava im pristup internetu. Korisnici GPRS su uvek dostupni i kada ne primaju i predaju podatke i predstavljaju samo alocirane resurse. GPRS se implementira sa GSM standardom tako da nema potreba za korišćenjem novih frekvencija. Radi uspostavljanja veze i prenosa podataka posredstvom GPRS-u neophodno je posedovati mobilnu stanicu koja se sastoji od uređaja koji može da bude mobilni ili stabilni i mora da poseduje pretplatnički identifikacioni modul tzv. SIM-kartica (Subscriber Identity Module-SIM). SIM karticu obezbedjuje mrežni operator, koji naplaćuje uslugu prenosa podataka. Sve komunikacije izmedju mobilne stanice odvijaju se preko bazne primo-predajne stanice (Base Transceiver Station- BTS). Aplikacije koje koriste GPRS svojastva mobine telefonije daju odlična rešenja za kontrolu sistema navodnjavanja, ali su ekonomski više zahtevna.

Satelitske radio komunikacije se nameću kao poželjno rešenje kada postoje velike topografske razlike koje ograničavaju uptrebu GSM/GPRS mreže [18]. Radio sistemi sa većom snagom, licencirani (npr. 5–10 W) sa modemima takođe mogu predstavljati rešenje, ali i na njih reljef može imati veliki uticaj. Ponavljačke stanice za radio-frekvencijske sisteme takođe mogu biti prilično skupe, posebno ako postoji potreba za komunikacijom na velikim udaljenostima kroz raznovrsnu topografiju.

Povećanje rastojanja za bezžični prenos podataka može da se izvede pomoću čvorova (nodles). Čvorovi osim funckije upravljanja (uključivanje i isključivanje rasprskivača, merenje od strane senzora) mogu da služe kao bezžični repetitori koji šalju informacije susednim čvorovima. Samo zadnji čvor ima mogućnost prenosa podataka na veća rastojanja, napr. GPRS [10].

Tablela 2. Prednosti i nedostaci mreže bezžično povezanih senzora [2].
Table 2 Advantages and disadvantages of distributed wireless sensor networks [2].

Prednosti	Nedostaci
- dozvoljava proizvođačima maksimiziranje njihove produktivnosti uz uštedu vode, - obezbeđuje dinamičku mobilnost i lako premeštanje i zamenu stanica, - efikasna koordinacija kontrolnih i izmerenih podataka, - upravljanje pomoću mreža za prenos podataka i jeftinih mikrokontrolera.	- energija potrebna za snabdevanje, - rezervacija širokog propusnog opsega, - greške u protokolima rutiranja, - elektromagnetne smetnje, - neujednačenost useva, - sinhronizovano prikupljanje podataka, - trajanje baterije senzora, - domet radija, - ometanje širenja radio signala lisnom masom useva.

Elektronski senzori, oprema za kontrolu i protokoli komunikacije dostigli su zadovoljavajući nivo razvoja kako bi ispunili zahteve koji postavljaju sistemi za navodnjavanje čije je upravljanje bazirano na specifičnostima u polju. Senzori postavljeni na polju ili komandnoj tabli mogu sakupljati podatke neophodne za upravljanje navodnjavanjem u realnom vremenu i prenositi informacije preko bezžične mreže do baznog računara ili kontrol panela.

Komercialno je dostupna oprema koja omogućava kontrolu na osnovu unapred zadatih vrednosti, ali sistem odlučivanja neophodan za automatsku kontrolu još uvek zahteva nadogradnju i poboljšanja. Izbor vrste komunikacionog sistema za daljinski pristup prvenstveno zavisi od lokalne i regionalne topografije, kao i troškova njegove ugradnje i korišćenja.

Komunikacioni sistem preko mobilnih telefona, satelitskog radija i sistem baziran na internetu omogućava operatoru pristup glavnom kontrolnom panelu ili baznom računaru sa bilo koje lokacije i u bilo koje vreme.

Kako bi se povećala efikasnost navodnjavanja i smanjila upotrebe vode, mora da se obezbedi upravljanje navodnjavanjem uzimajući u obzir specifičnosti lokacije i vremenske uslove. Ovo je vrlo složena i izazovna tema istraživanja, jer na produktivnost vode u usevima ne utiču samo životna sredina i zemljište, već i vrsta usjeva i njegova faza razvoja. Kada dođe do promene u lokalnom okruženju kao što su temperatura i vlažnost, senzori su zaduženi da registruju navedene promene, a sistem donošenja odluka o navodnjavanju mora da uzme u obzir ove promene i u skladu s njima ažurira strategiju navodnjavanja. Od izuzetnog značaja je i dalji razvoj i primena bežičnih senzora radi povećanja efikasnosti, produktivnosti i profitabilnosti poljoprivrednih operacija.

ELEMENTI AUTOMATSKOG UPRAVLJANJA SISTEMA ZA NAVODNJAVANJE

Automatske pumpne stanice

Savremene pumpne stanice projektuju se kao automatske uz primenu frekventnih regulatora (Variable Freqency Drive VFD), koji se postavljaju na svakom elektromotoru koji pokreće pumpu za vodu (sl. 2). Frekventni regulator omogućava rad pumpe u režimu od 0 do 100% protoka.

Na taj način obezbeđeno je minimalno vreme pokretanja uz kontrolisano puštanje eloktromotora u rad radi izbegavanja preopterećenja i pada napona u sistemu za snabdevanje električnom energijom. Pumpa u toku snabdevanja sa vodom radi obezbeđenja vrhunskih performani, zbog svojih karakteristika i optimalnog stepena korisnog dejstva koristi se u režimu 50 do 100% protoka. Za svaku pumpu se kontinualno meri pritisak, protok i angažovana snaga elektromotora, i izmereni podaci se procesuiraju i optimizuju po kriterijumu minimalne potrošnje energije. Korišćenjem frekventnih regulatora moguće je obezbediti potpunu dinamičku kontrolu pritiska uz uključivanje potrebnog broja pumpi za vodu koje rade u optimalnom radnom režimu uz minimalni utrošak električne energije. Na ovaj način izbegnuto je upravljanje pritiskom korišćenjem prigušnica ili bajpasa, koje je energetski izuzetno neefikasno. S druge strane, dinamička kontrola pritiska prati promene u protoku, a takođe može i da trenutno prekine snadbevanje sa vodom. Korišćenjem frekvantnog regulatora, pored značajnog smanjenja energije, smanjuje se habanje sistema i manje je angažovanje ljudskog rada.

Automatizacija rada pumpnih stanica izvodi se najčešće preko SCADA sistema upravljanja i daljinskog nadzora (sl.1). SCADA (Supervisory Control and Data Acquisition) je sistem koji služi za automatizaciju opštih procesa, odnosno koji se koristi za prikupljanje podataka sa senzora i instrumenata lociranih na udaljenim stanicama i za prenos i prikazivanje tih podataka u centralnoj stanici u svrhu nadzora ili upravljanja. Primarna svrha primene SCADA sistema je da unapred daju upozorenje na problem koji može nastati.

Slika 2. Frekventni regulator, PLC kontroler i SCADA sistem, [19].
Figure 2. Variable Freqency Drive, PLC controler and SCADA system, [19].

Komunikacija se ostvaruje posredstvom GPRS sistema, upotrebom GSM/GPRS modema i rutera. Na radnim mašinama postavljaju se PLC kontroleri (Programmable Logic Controller - programabilni logički kontroler). PLC kontroleri se koriste za automatsko upravljanje procesima - prate ključne parametre procesa posredstvom priključenih senzora i davača, i shodno memorisanom programu, generišu pobudu kojom deluju na proces (posredstvom aktuatora). Naponski i strujni opseg modula mora biti usaglašen sa električnim karakteristikama sistema ili uređaja s kojim se PLC kontroler povezuje. Da bi se zadovoljili najrazličitiji zahtevi u pogledu naponskih i strujnih opsega, proizvođači PLC kntrolera nude palete ulaznih i izlaznih modula deklarisanih za različite naponske/strujne opsege.

Od PLC-a se očekuje da periodično očitava (unosi) signale sa senzora, izvršava određen broj aritmetičko-logičkih operacija (u skladu sa zadatom funkcijom) čiji rezultati se prenose na izvršne organe ili neke druge indikatorske uređaje. Pored toga, sa istom ili nekom drugom učestanošću, PLC treba da održava komunikaciju (razmenjuje podatke) sa nekim drugim računarskim sistemima u mreži.

Očitavanja i praćenja na zalivnom polju

Da bi sistem automatskog upravljanja mogao kvalitetno i pouzdano da radi kao deo sistema za navodnjavanje od presudnog značaja su očitavanja izvedena u polju, na parceli na kojoj se izvodi navodnjavanje. Vrsta i broj očitavanja može da bude različit, pri čemu se najčešće koriste očitavanja za:

- geolokaciju zalivnog polja i položaj mašine za navodnjavanje,
- vlažnost zemljišta,
- temperaturu zemljišta,
- očitavanje EC i pH vrednosti vode kojom se izvodi navodnjavanje,
- meteorološke podatke: temperatura vazduha, brzina vetra, intenzitet globalnog zračenja, količina padavina,
- koeficijent evapotranspiracije,
- očitavanje protoka i pritiska distribuirane vode, ...

Očitavanja se izvode u realnom vremenu, a dodatno se koriste podaci o vremenskoj prognozi i donose odluke o navodnjavanju. Sistem automatskog upravljanja istovremeno šalje izveštaje i obaveštenja (alarme) o trenutnim stanjima funkcionisanja sistema.

Merenje vlažnosti zemljišta

Upravljanje navodnjavanjem zahteva kvantitativno poznavanje kada i koliko vode treba primeniti u zavisnosti od potreba gajene biljke, a što zahteva upotrebu merne tehnike za merenje količine vode u zemljištu. Određivanje vlažnosti zemljišta može da se izvodi na parceli i u laboratoriji. Klasične tehnike merenja vlažnosti zemljišta uključuju termo-gravimetrijske metode, tenziometar, neutronske metode i metode gipsanog bloka [20]. Moderne tehnike merenja vlažnosti zemljišta koriste: senzore otpornosti zemljišta, dielektrične provodnosti (vremenske TDR, frekventne FDR i kapacitivne), senzore toplotnog fluksa, mikro-elektro mehaničke sisteme i optičke tehnike [21]. Odluka o tome koja tehnika merenja će biti primenjena zavisi od svrhe merenja, uslova zemljišta i useva, željene tačnosti, cene i trajnosti senzora, lakoće rada i tumačenja podataka i drugih faktora [22]. Precizno određivanje sadržaja vode u zemljištu predstavlja osnovni element za upravljanje prilikom navodnjavanja i osnovna komponenta u studijama koje se odnose na: kretanje vode u zemljištu, stres useva usled nedostatka vode, evapotranspiraciju, hidrološko modeliranje, modeliranje zahteva useva za vodom u zavisnosti od fenofaze razvoja.

Da bi senzori očitavali validne podatke moraju se pre njihove primene kalibrirati u zavisnosti od uslova sredine u kojima se koristite. Senzori mere električne veličine, ali određivanje granica početka i kraja navodnjavanja određuje se prema sili kojom se drži voda u zemljištu, tj. koliko je pristupačna biljkama.

Voda u zemljištu je dostupna biljkama u opsegu između punog poljskog kapaciteta (PVK), kada se molekule vode drže silom manjom od 0,1 bar, pa sve do tačke venjenja koja za većinu gajenih poljoprivrednih kultura ne prelazi 15 bar. Mehanički sastav zemljišta, retencione krive i vodne konstante treba odrediti laboratorijskim merenjima za konkretni tip zemljišta [22]. Za većinu žitarica preporučuje se početak navodnjavanja kada količina dostupne vode opadne za 50%, a za osetljivije kulture (povrće) za 40% ili čak manje [23]. Ukoliko postoji ograničenje po pitanju količine dostupne vode i kapaciteta sistema za navodnjavanje ove vrednosti treba da budu još niže.

Slika 3. Merenje vlažosti zemljišta, postavljanje, očitavanje i daljinska komunikacija, [22].
Figure 3. Soil moisture measurement, installation, reading and remote communication, [22].

Radi precizne kontrole vodnog statusa zemljišta potrebno je instalirati minimalno tri senzora na svakih 30 cm dubine, a poželjno je da se postavi i četiri senzor, što predstavlja dubinu prostiranja korenovog sistema većine redovnih useva (sl. 3).

Početak navodnjavanja pre reproduktivne faze useva treba da se odredi na osnovu prosečnih vrednosti prva 2 senzora (do 60 cm) a nakon što usev dostigne reproduktivnu fazu u obzir treba uzeti prosek 3 senzora (do 90 cm). Međutim, za peskovito zemljište, prosek merenja gornja 2 senzora treba da se koristi kao okidač tokom cele sezone rasta.

Korišćenjem senzora za merenje vlažnosti zemljišta u polju, dobija se uvid u stanje u realnom vremenu po relativno pristupačnoj ceni, i kao samostalna metoda ili u kombinaciji sa ostalim metodana, pružaju smernice kada i koliko navodnjavati [24]. U većini slučajeva navodnjavanjem treba zemljištu nadoknaditi vode do 90% PVK, kako bi se ostavio prostor za dodatno prihvatanje vode usled eventualnih padavima.

Elementi automatskog upravljanja na visokim samohodnim mašinama za navodnjavanje

U ovom radu, poseban akcenat dat je na visoke samohodne mašine tipa center pivot ili linear, kojima se na području AP Vojvodine navodnjava oko 80% površina (interna dokumentacija JVP Vode Vojvodine, Hidrozavod DTD, Agroaqua d.o.o., Agrosavet Irrigation d.o.o.). Na globalnom nivou, samo približno 17% visokih samohodnih sistema koristi napredne tehnologije za nadgledanje i upravljanje sistemima za navodnjavanje [25]. Iz navedenog proisitiče ogromni potencijal po pitanju unapređenja navodnjavanja.

Visoke samohodne mašine opremaju se kontrolnim panelima sa različitim nivoima kontrole, pogodnostima i opcijama praćenja. Najjednostavniji kontrolni paneli se isporučuju sa osnovnim komandama za:

startovanje, promenu smera kretanja, promenu brzine kretanja čime se utiče na normu navodnjavanja, uključivanje i isključivanje snabdevanja sa vodom i merenje protoka vode, kao i kontrola napona u električnom sistemu mašine.

Naprednije verzije imaju funkcije koje čine navodnjavanje lakšim i efikasnijim. Postoji mogućnost određivanja trenutne pozicije mašine i njeno zaustavljanje u zavisnosti od ograničenja koja se nalaze na parceli. GPS uređaji mogu da se postavljaju na stožeru, na kraju krila na poslednjem tornju i na kraju kornera, čime je omogućeno vođenje kornera (sl.4). Kontrolni paneli sa najvišin nivoom opreme omogućavaju preciznou kontrolu navodnjavanja, đubrenja i zaštite u cilju očuvanja i unapređenja efikasnosti poljoprivredne proizvodnje. Takođe mogu da upravljaju radom krajnih rasprskivača (topova).

Slika 4. GPS uređaji na visokim samohodnim mašinama za navodnjavanje
Figure 4. GPS devices on high self-propelled irrigation machines

U zavisnosti od nivoa opremljenosti, kontrolni paneli mogu da se povežu na dodatne terminalne jedinice za daljinsko povezivanje i upravljanje, ili su one već integrisane u njima, kako bi se omogućilo daljinsko upravljanje radom mašine. Visoke samohodne mašine starije proizvodnje imaju istalirane mehaničke, ručno upravljane kontrolne panele (sl. 5).

Ukoliko imaju električni pogon točkova postoji mogućnost njihove nadogradnje čime se dobija mogućnost daljinskog upravljanja, GPS pozicioniranje i mogućnost primene varijabilne norme navodnjavanja (VRI) promenom brzine kretanja.

Slika 5. Mogućnost nadogradnje kontrolnih panela
Figure 5. Possibility to upgrade control panels

Precizno navodnjavanje (precise irrigation, PI) tačno određenom količinom vode u zavisnosti od potrebe biljaka i usaglašavanje norme navodnjavanja sa konkretnim karakteristikama zemljišta, eliminiše mogućnost prevlažiavanja i oticanja vode.

Pomoću visokih samohodnih mašina mogu se ostvariti različiti nivoi preciznosti varijabilne norme navodnjavanja (variable rate irrigation, VRI).

Najniži nivo preciznosti VRI ostvaruje se promenom brzine kretanja mašine. Srednji nivo preciznosti VRI postiže se istovremenim uključivanjem/isključivanjem grupe rasprskivača po sektorima, a potpuno varijabilna kontrola se postiže preciznim uključivanjem/isključivanjem svakog pojedinačnog rasprskivača. Uključivanje i isključivanje rada pojedinih ili grupe rasprskivača najlakše se izvodi korišćenjem elektromagnetnih ventila. Izborom dužine trajanja uključenosti u toku jedne minute utiče se na promenu norme navodnjavanja a da se pri tome ne remeti režim rada rasprskivača [26]. Primena VRI posebno je opravdana kada se na jednom zalivnom polju gaje različite kulure koje imaju različite potrebe za vodom, zemljište nije homogeno po mehaničkom sastavu, postoje visoka područja usled kojih dolazi od odticanja vode, kao i niska, plavna područija, prepreke kao što su objekti, staze i putevi, i osetljive oblasti sa stavnovišta zaštite životne sredine.

Programiranje najnižeg nivoa preciznosti VRI može da se izvodi direktno na samom kontrolnom panelu u zavosnosti od prethodno utvrđenih ograničenja i karakteristika parcele ili da se preuzme program varijabilnog navodnjavanja konkretne parcele generisan od strane specializovanih softvera. Glavni softver za upravljanje sistemom za navodnjavanje može da bude stacioniran na računaru smeštenom u kontrolnom centru na imanju ili na cloud platformi, i mora da ima kapacitet za veći broj proračuna radi analize podataka i davanje izveštaja (upravljanja), skladištenje podataka i online ažuriranja, a takođe i mogućnost povezivanja sa ostalim softverima (android) i uređajima (tablet i mobilni telefon). Na osnovu izmerenih informacija iz različitih resursa (očitavanja u polju, režim rada mašine za navodnjavanje, rad pumpne stanice) i uz istovremeno korišćenje modela potreba biljaka za vodom i hranivima u zavisnosti od faze razvoja biljaka, kao i eksternih izvora podataka (vremenska prognoza), glavni softver donosi komandnu odluku kada, gde i koliko navodnjavati. Treba napomenuti da se u svakom trenutku može prekinuti automatsko i preći na ručno, daljinsko upravljanje od strane operatora.

Benefiti automatizacije navodnjavanja

Automatizacijom navodnjavanja omogućen je znatno veći komfor u radu i upravljanju sistemom za navodnjavamje (automatsko uključivanje, daljinska kontraola i upravljanje). Preciznim vođenjem sistema dolazi do značajne uštede resursa (pogonska energija, voda, đubriva, hemijska zaštitna sredstva, ljudski rad). Na osnovu vrednosti izmerenih u polju o stanju zemljišta i potrebama biljaka povećava se preciznost raspodele i efikasnosti korišćenja vode. Automatski i daljinski upravljan sistem navođenja predstavlja preduslov za primenu VRI, čime se uvodi precizno navodnjavanje PI (precise irrigation). Preciznost u poljoprivredi postaje imperativ. Teoretski, precizna primena vode je podjednako važna kao i primena drugih repromaterijala u poljoprivredi za koje se zahteva visoka preciznost količine i prostornog rasporeda (seme, zaštitna sredstava i đubrivo). Uštedom vode, istovremeno dolazi do uštede energije, đubriva i zaštitnih sredstava. Postojeća oprema za automatizaciju karakteriše se univerzalnošću po pitanju korišćenja na različitim tipovima zalivnog sistema.

Ugradnjom ili dogradnjom opreme za automtsko vođenje procesa navodnjavanja omogućena je:

- kontrola zalivnog sistema,
- alarmi,
- rad start/stop sistema,
- podešavanje ciklusa,
- kontrola uređaja za fertirigaciju,
- podešavanje EC i pH vrednosti,
- monitoring kompletnog sistema,
- čuvanje istorije događaja i prikupljenih podataka i
- automatski režim rada na osnovu prikupljenih podataka.

Informacije u realnom vremenu pružaju upozorenja i pomažu da se utvrde problemi istog momenta čim se oni pojave, i što omogućava brzu i efikasnu reakciju. U zavisnosti od vrste utvrđenih promena, automatski sistem može samo da snima promene, izdaje upozorenja, ili automatski zaustavlja rad celog sistema.

Postavljanjem mobilnih stanica sa modemima na kontrolni panel samohodnih visokim mašinama za navodnjavanje, omogućeno je njihovo daljinsko upravljanje, pri čemu se komunikacija odvija putem GSM/GPRS mreže.

ZAKLJUČAK

Navodnjavanje (kontrola) zasnovano na senzorima koji su daljinski povezani i daju informacije u realnom vremenu, utiče na povećanje efikasnosti korišćenja vode i ekonomsku efikasnost. Potencijalna ekonomska korist ovog sistema za navodnjavanje leži u smanjenju troškova inputa ili povećanju prinosa za iste inpute. Tradicionalne tehnike navodnjavanja poljoprivrednih površina zahtevaju ručnu intervenciju. Pomoću automatizovane tehnologije navodnjavanja ljudska intervencija može se svesti na minimum. Daljinsko komunikacija i upravljanje predstavljaju preduslov za funkcionisanje automatskog sistema navođenja, a koji opet predstavlja preduslov za primenu varijabilne norme navodnjavanja.

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AUTOMATIC CONTROL OF IRRIGATION SYSTEMS

Ponjičan O.[1], Učur S.[2], Vučinić Ž.[3], Samardžić B.[4], Sedlar A.[1], Turan J.[1], Višacki V.[1], Vasić F.[1]

University of Novi Sad, Faculty of Agriculture, Department of Agricultural Engineering, Square Dositeja Obradovića 8, Novi Sad, R. Serbia
[2]Agroaqua d.o.o, Arona Zagorice 1, Veternik, R.Serbia
[3]Hidrozavod DTD, Petra Drapšina 56, Novi Sad, R.Serbia
[4]Agrosavet-Irrigation d.o.o, Vladimira Garjanskog 2, Vrbas, R.Serbia

Abstract: Autonomous irrigation systems have been developed to optimize water use in agricultural production and reduce human labor consumption. These systems should be able to be remotely controlled and managed any times by the farmer. The use of sensors and remote reading capabilities are needed to collect real-time data on crop condition, development phase and other parameters related to weather, crops and soil to support intelligent and efficient irrigation management systems.

The sensors communicate remotely with the central control unit and the main control unit, which processes a large number of input parameters, and using complex algorithms generates an output control function: when, where and how much to irrigate. The operator must also be able to access and operate the irrigation machine in real time from anywhere and ani time. Remote wireless communication can take place in several ways: Wi-Fi, radio and GSM/GPRS. The choice of communication system depends on the topography and costs. Further development of wireless sensor applications in agriculture is needed to increase the efficiency, productivity and profitability of each agricultural operation, and thus agricultural production as a whole.

Keywords: *automatic control, remote control and management, precision irrigation, environmental protection.*

Napomena*: rad je nastao kao rezultat istraživanja koje finansira Ministarstvo prosvete, nauke i tehnološkog razvoja Republike Srbije, na osnovu ugovora o realizaciji i finansiranju naučnoistraživačkog rada u 2021. godini. Evidencioni broj ugovora: 451-03-9/2021-14/200117.*

Prijavljen: *Submitted*:	**15.10.2021.**
Ispravljen: *Revised*:	**25.11.2021.**
Prihvaćen: *Accepted*:	**30.11.2021.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLVII
Broj 1, 2022.
Strane: 15 – 33

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLVII
No. 1, 2022.
pp: 15 – 33

UDK: 665.353.4;631.15(669)

Original scientific paper
Originalni naučni rad
doi: 10.5937/PoljTeh2201015A

DEVELOPMENT OF SUSTAINABLE PRODUCTS FROM OIL PALM TOWARDS ENHANCING NATIONAL FOOD SECURITY: A REVIEW

Assian Ubong Edet*[1], Okoko Joseph Udoudo[1] , Alonge Folarin Akindele[1], Udoumoh Unwana Iniobong[1] , Ehiomogue Precious[1]

[1]Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, Akwa Ibom State, Nigeria

Abstract: Increasing threat insecurity of food production in Nigeria is perceived in almost all parts and areas of the national food production. Food insecurity seems to be a global challenge that has a lot to do with surge in energy demand, population growth, climate change and competition for land, food and water. The rural settlements are more prone to irregular food supply, malnutrition, and low quality foods, high cost of food items and even widespread lack of food. This has created a serious concern towards national food security. However, the availability of agricultural and food products could mitigate this menace. So, in an attempt to arrest this situation, this paper presents a review of the development of some sustainable products from oil palm towards enhancing national food security. In a nutshell, it highlights the overview of oil palm tree, its classification, current and future mechanization, processing of oil palm fruit from the bunch to crude palm kernel oil extraction and other by-products, application of the products; and production capacity of palm oil from 2010 to 2020 in Nigeria.

*Corresponding Author. E-mail address: assian4real@yahoo.com

Besides, nutritional composition of palm oil and palm kernel oil, rationale for the use of oil palm and its derivatives in the development of sustainable food and allied products are also discussed.
Furthermore, concept of sustainable palm oil, some food products made from palm oil and its functional attributes; and the development of some selected food products with palm oil as one of the major ingredients are also highlighted.

***Key words**: Oil palm, sustainable products, national, food, security*

INTRODUCTION

The alarm of threat to national food security in Nigeria had been sounded for some years now [1]. Food security is referred to as possessing sufficient food, with adequate nutrient, satisfactory and safe all-round the year in a manner that permits everybody to ensure a healthy and energetic life. It also means the ability to source for nutritive and adequate food, by means of simple trading, incomes or productions [2]. Food security is a multi-facet issue with socio-economic and environmental aspects. Regrettably, out of 206, 139, 589 people in Nigeria, 25,600,000 (about 12.4 %) are undernourished [3, 4]. Food is one of the basic necessities of life. Though, several efforts have been sunk into enhancing the quality and quantity of world food production and supplies, food insecurity still remains dominant in Nigeria. Food insecurity has a significant correlation with malnutrition [5]. Many social problems such as riots and civil unrest are a few impacts of failure to guarantee food security in many major cities of the world. Food insecurity is related to other universal issues, such as surge in energy demand, population growth, climate change and competition for land, food and water [6]. However, the poverty rate in Nigeria is alarming, though the largest economic giant of Africa in 2014. About 70% of the Nigerian population is living on less than a dollar per day [7]. Before the discovery and exploration of crude oil in 1970s, Nigeria had been one of the largest producers of agricultural products such as cocoa, groundnuts, palm oil, palm kernel oil and its derivatives, etc., [8]. The agricultural sector hitherto had been the main stay of the Nigerian economy. In fact, the main economic stay of some countries of the world such as Liberia, Somalia, Malaysia, Brazil, United States of America, India, China and Indonesia centers on agriculture [9,10]. Unfortunately, Nigerian crude oil and gas sector had gradually rendered agricultural sector less significant to the government, thus, rendering the nation to be dependent on imported foods [11]. The rural settlements are even more susceptible to irregular food supply, malnutrition, and low quality foods, high cost of food items and even widespread lack of food. This condition is more common in the northern parts of Nigeria [12]. Thus, this in turn has created a serious concern towards national food security. However, the availability of agricultural and food products could go a long way in cubing this situation. In an attempt to arrest this unpleasant trend, this paper reviews of the development of sustainable products from oil palm towards enhancing national food security. The specific objectives were to: (i) identify some products derived from oil palm; and (ii) highlight processing technologies in the development of some sustainable food products from oil palm.

This paper would provide information for small and medium-scale industrialists who may desire to venture into palm oil mill business and perhaps develop some food products for oil palm.

OVERVIEW OF OIL PALM TREE

The oil palm tree (*Elaeis guineensis*) is a great economic and perennial plant. It is indigenous to tropical areas. Its origin could be traced from Africa, predominantly in the southern parts of Ghana and Nigeria, but grown commercially in Southeast Asia and Southern America. It grows within the altitudes of 500 m above sea level in warm climatic zone and produces its fruits in bunches that weigh between 10 to 40 kg. A mature oil palm tree is a single-stemmed plant which could grow up to 20 m tall.

The leaves are pinnate and may be 3 to 5 m long. A young palm tree may produce about 30 leaves a year. However, its flowers are densely formed in clusters. Each distinct flower is very small, with three petals and sepals. Its fruit takes about 5 to 6 months to mature from the period of pollination. Its fruit is reddish, about the dimension of a big plum. Its fruits are harbored in large bunches. Each fruit is composed of pericarp (an oily-fleshy external layer), with single, double or triple seed(s) palm kernel (s), depending on the size and variety. The individual fruit weighs from 60 to 70 grams. It is very rich in vegetable oil [13, 14]. The new cultivars developed by modern breeding technology, under perfect atmospheric or climatic factors and decent management practices are high yielding breeds that could produce more than 19 tonnes of bunches with healthy fruits per hectare per year [15]. The fresh oil palm bunch, as shown in Figure 1, composed of fruits rooted in spikelets which are grown on a major stem [16]. Ideally, the oil palm bunch (Fig.1), is composed of 60.0 – 65.0% fruits, with 21.0 – 23.0% palm oil, 5.0 – 7.0% kernel, and 44.0 – 46.0% mesocarp. Furthermore, the climatic conditions or factors could make expected high yield impracticable to achieve, because, sometimes the climatic factors are generally less than ideal. However, the rainfall may be unpredictable, especially in the Western and Central parts of Africa; hence the trees may be struggling to strive due to inadequate water supply [15]. Oil palm tree is classified based on the morphology of their fruit. The oil palm fruit has endocarp (shell thickness) and mesocarp content [17]. It has three (3) major varieties: namely, the Dura, Tenera and Pisifera as depicted in Figure 2. Dura have large kernel and a very thin pericarp, which contains about 40 -70% oil by weight and with shell thickness of about 2 - 5 mm; Tenera has medium kernel with a thick pericarp of about 60% fruit weight containing a higher % of oil and 1 mm to 2.5 mm shell thickness. Their structural characteristics are shown in Figure 3.

Fig. 1. Fresh palm bunch

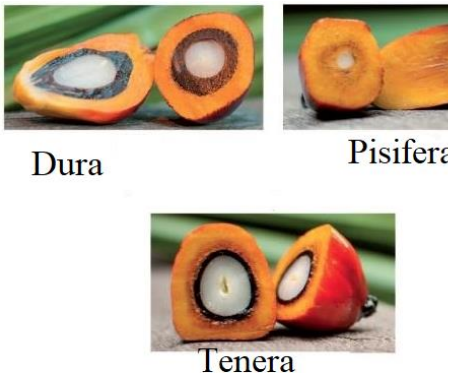

Fig. 2. Three major palm fruit varieties

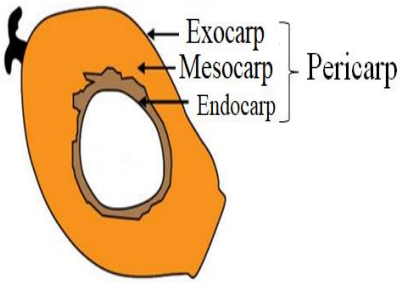

Fig. 3. Cross section of palm fruit showing its structural characteristics

CURRENT / FUTURE MECHANIZATION IN OIL PALM PLANTATION

Technology and invention are very important aspects in the cultivation of oil palm, harvesting and processing of its produce. They are keys to promoting healthy competition among nations' oil palm industries in the global market. Hence, the implementation of mechanization and automation will go a long way in abating the current challenge of labor shortage, eradicating drudgery associated with whole production processes and boosting productivity. Several agencies /companies such as Malaysian Oil Palm Board (MOPB), Sime Darby, University Putra Malaysia (UPM), Fedepalma / Cenepalma, Deere & Company, Allis-Chalmers Manufacturing, Lovol and others have developed many equipment / machines for use in oil palm plantation operations [18]. Nevertheless, a shift from conventional mechanization to robotic (modern) supported mechanization system cannot be overemphasized because of its unique advantages over conventional mechanization in agriculture.

Pre-harvesting Operations in Oil Palm Plantation

Several machines and technologies have been developed in this regard include: artificial intelligence (AI), robotic systems, unmanned aerial vehicles and manned machines etc.

(a) Drone System,* Manned Machines and Unmanned *Aerial Vehicles

Drone, in high-tech terms, is an unmanned aircraft system or aerial vehicle which may be flown by a robot that is remotely controlled or independently through software application. This application is monitored by flight plans. A drone may compose of three or more propellers which it uses to fly in any direction. Drone system could be used to auto count oil palm trees and possibly forecast their yield which may be cumbersome to count using the convention technique [19]. Its images generated could locate precise empty spots in the field which could be eliminated after a careful confirmation by team and subsequent action taken. Areas prone to floods can be identified through its imagery, and this could lead to redesigning of the drainage system.
Aerial normalized difference vegetation index (NDVI) which is incorporated in it, is employed to track and manage diseases where affected plants, exact location can be identified and specific treatment given instead of mass treatment.

Locations where fertilizer application is required can be spotted out using the web portal imaging. The use of drone system offers faster rate of fertilizer application/ spraying.

For instance, it takes about 20 minutes to cover one hectare of oil palm plantation. Besides, oil palm planter can be auto guided using Multi-Global Navigation Satellite System (GNSS) by: (i) designing the planting pattern and determining the planting area boundary coordinate; (ii) making geo-reference using ArcGIS; (iii) using Tracy software application to stake out process; and (v) indicating location with wooden spikes [20].

(b) Artificial Intelligence (AI)

Artificial intelligence (AI) in agriculture is the science of building intelligent equipment / machines/ gadgets that are used in agriculture in order to increase crop yield but at a minimal production cost. Artificial intelligence is aimed at imitating and surpassing human intelligence in solving problem [21]. With AI, computers virtually "see" as humans see. By installing mobile technologies with AI and built-in computer vision, AI sensors can spot weeds and then decide which herbicides to use within the safe limit to get rid of them, instead of spraying the entire oil palm plantation [22]. Mobile phones could also be connected with cloud data storage systems where managers can get real-time data from workers concerning the plantation and field activities for quick, precise decision making and judicious action. Furthermore, precision farming (PF) uses AI technology to help in identifying, pests, poor plant nutrition on farms, etc. It uses data loggers, yield monitors, Geographical Position System (GPS), Geographical Information System (GIS) and Internet of Thing (IoT) facilities, sensors etc. These tools are fitted on the aerial machines for data collection.

However, the application of PF is dependent on the success of field mechanization processes, assertiveness and management willingness to embrace the technology [20]. Farmers can use AI to generate periodic forecasting models to enhance accuracy and increase productivity.

Through the use of AI and cognitive technologies such as Chatbots, farms could run more proficiently, with less number of workers still producing the reasonable quantity of produce.

Consequently, application of AI improves produce quality, productivity, reduces wastage, minimizes environmental pollution and conserves energy.

Harvesting Operations in Oil Palm Plantation

(a) Manned Machines and Unmanned Aerial Vehicles

The harvesting operations in oil palm plantation involve: (i) cutting of fronds and ripe bunches; (ii) bunch stalk trimming; (iii) reorganizing and stacking of fronds; (iv) gathering of harvested bunches and loose fruitlets; and (v) transportation of fresh fruit bunches (FFB) to tractor hopper or mill. Manned machines available for use at this stage are as follows: (i) Motorized cutter: The C- shaped crescent is used in harvesting about 700 to 1000 ripe oil palm bunches per day and records a reduction of 2 to 3 labors; (ii) Motorized chisel: This uses its chisel to cut down 80 FFB per hour per labor and could prune the oil palm leaves at about less than 2 m high; (iii) Mechanical harvester:

It can cut about 4.0 to 6.0 ton FFB per day and 80 to 100 hectares per machine at 6.0 to 10.0 m high, and carry them to accessible road; (iv) Compact transporter. It can transport from 3 to 5 ton FFB per day along narrow terrain areas; (v) Grabber:

It is like an arm mounted on a tractor which uses a three-blade clamp to hold about 20-30 ton FFB/day; (vi) Loose fruitlets collector (MPOB TT No.57): This is a mechanism installed on a three-wheeler with the capacity to suck 1400 kg to 1700 kg of loose fruitlets per day.

Another brand of loose fruitlets collector (MPOB TT No.419) has the ability to collect 30 to 60 kg of palm fruitlets per working hour. The fruitlets get into elastic crannies of the rod depending on the surface of the soil where the process is carried out; (vii) Loose fruitlets separator: This separator can be stationary and movable unit, and can separate 97% of 1 clean ton of fruitlets per hour with the fan speed of 1600 rpm; (viii) Motorized injector: It is mechanism for introducing liquid chemicals into the palm stem, e.g. in controlling Ganoderma. About 40 to 50 trees could be injected with it per day [20]. Unmanned aerial vehicle images embedded with YOLO model could identify oil palm loose fruits. The model has adopted numerous enhancements where closely and heavily connected neural network is featured for reprocessing. The multi-layer detection of minute targets, prior box optimization, and swish activation function to get exact bounding box record are also embedded. Based on the report of a study, an excellent mean accuracy of 99.76% as well as 34.06 ms detection time was obtained [23].

(b) Artificial Intelligence (AI)

The data relating to the application of AI on harvesting and collection of FFB can be uploaded to the computer system at the estate's office for immediate actions [20].

With AI agriculture bots or robotic systems, FFB could be harvested at a higher volume, faster pace than human labour with more accuracy based on quick auto identification of the ripe bunches [21].

Future Realities in Oil Palm Mechanization

A shift from conventional mechanization to robotic (modern) supported mechanization systems such as drone systems, artificial intelligence (AI), robotic system, unmanned aerial vehicle, etc. cannot be overemphasized.
Mechanization packages could be developed based on machine structures and field operations.
Weather proofing could also be developed to maintain field infrastructures and promote efficient mechanization. Mechanization systems can be replaced by embracing and adopting automation and robotic technologies [20, 24].

PROCESSING OF OIL PALM FRUIT

The palm fruits are harvested and thereafter subjected to series of processing stages such as bunch reception, threshing (stripping or detachment), sterilization (heating of the fruits), digestion (pounding), palm oil extraction/ clarification, nut-fibre separation, nut drying and cracking, kernel separation, kernel crushing and pressing as presented in Figure 4. However, two methods are used. The principles involved are the same but the difference is in the facilities employed. The cracked nut mixture, shell fragments and kernels are shown in Figure 5. [2,15].

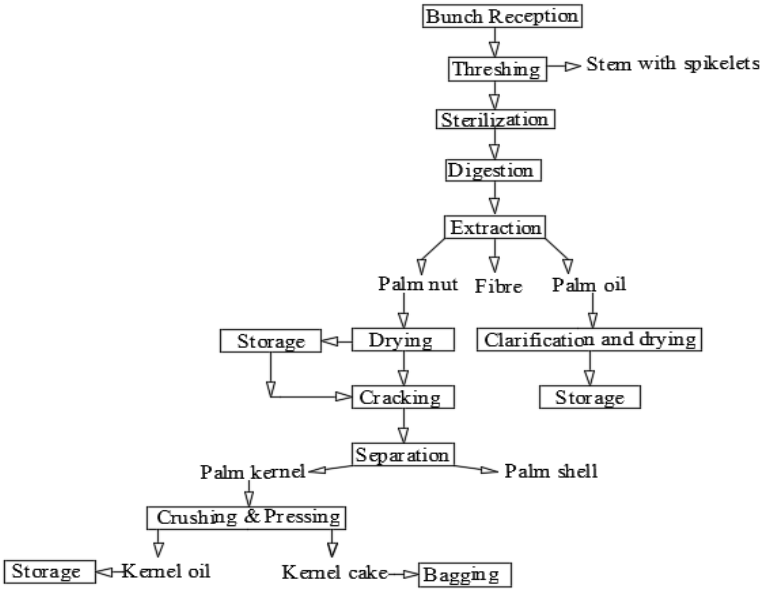

Fig.4. Stages involved in palm fruits processing into palm oil, kernel oil and kernel cake

(a) (b) (c)

Fig. 5. (a) Cracked nut mixture; (b) Separated shells from cracked nut mixture; (c): Separated kernel from cracked nut mixture.

Methods of Processing of Oil Palm Fruit

Traditional Method of Processing

Traditional method of processing palm fruit involves the following:

a) Threshing

This is the process of detaching palm fruits from their bunches. The bunches are cut into bits with either a machete or an axe, then water-sprinkled, covered with plantain or banana leaves and left for two to three days. This promotes the separation of fruits from the spikelets by hand. Small-scale operators employ the waste /empty bunches as manure or cooking fuel.

b) Heating

The fruits are boiled in a drum containing water. The heating process aids in:

I Inactivation of enzymes responsible for splitting the oil, and prevention of hydrolysis and oxidation.

II Coagulating microscopically dispersed protein in the cell that bears oil. It permits the oil-bearing cells to be collected together for easy flow.

III Softening the the pulp structure for easy detachment of fibrous material and its contents.

c) Pounding

Pounding is done with a big mortar and pestle. The mortar is made from a big drum placed in a dug ground. Pounding helps in detaching the mesocarp from the palm nut.

d) Extraction

Extraction could be done by hand picking or using manually operated machine.

I Hand picking: In a small-scale operation, hands are used to select out the kernel and nuts. Then, the oil is pressed out using hand or sack bag from the fiber and collected into petroleum drums or plastic drums. This method is laborious and time-consuming. The selected fibre is covered to internally generate heat by exothermic reactions, for about 2 to 3 days. Then, the fibre is pressed using a spindle press mechanism to get back the rancid-type of palm oil that is used in making soap. The fibre is now collected as dried matter and kept for use as biomass (fuel).

II Use of manually operated machine: The pounded mixture is emptied into a screw press machine with cylindrical perforated sides. When the T-shaped iron bar fixed to the screw is rotated manually, a flat metal plate presses the pounded mixture and forces the oil to flow out [25].

e) Nut Drying

The nuts are usually sun-dried by spreading them on a bare ground or floor for some days depending on the sun intensity. After this stage, the nuts could be stored in silos, bins etc., or subjected to cracking.

f) Nut Cracking

Cracking palm nuts is commonly done by stone-arrangement and mortar/pestle method. The stone arrangement employs impact principle, where a nut is placed on a leveled stone and another stone (as hammer) is used to crack it.

It is commonly done by women and children. This technique is primitive, inefficient kernel recovery, uneconomical, labor intensive and injurious to the operator [26].

g) Separation of Cracked Nut Mixture

Children and women are used in picking out kernels from cracked nut mixture. These people make income from this process. The shell fragments left are collected for many applications.

h) Palm Kernel Oil Extraction

Kernels are normally heated (roasted) in a vessel until dark brown crude palm kernel oil is collected and stored. It may be used by locals as medicine and body cream [25].

Modern Method of Processing

a) Bunch Reception

The fresh fruits are received, emptied into wooden boxes and weighed. In a large scale mill, trucks loaded with the fruit are made to pass through the weighing bridge directly and the weight noted. It is worthy to note that the quality of bunches received would affect the quality standard of the end-products. The mill could only abate further deterioration.

b) Threshing (Stripping)

The fresh bunch mainly comprises fresh fruits. In a modern mechanized process, a rotating or fixed drum is fitted with rotary beating bars. These bars help in detaching the fruit from the bunch, leaving the spikelets on the major stem. In larger mills, the bunch waste is incinerated into ash. The ash obtained is very rich in potassium which could be used in making fertilizer for plant use [15].

c) Bunch Sterilization

Sterilization involves the use of wet-heat treatment operated at high temperatures to loosen the fruits. Sterilization in other words means cooking. It normally uses hot water or pressurized steam. The cooking action serves several purposes as already explained in traditional method. The steam breaks down resins and gums. During frying, foams are formed as a result of the presence of gums and resins. Gums and resins are water-soluble while others may be induced to be soluble in water.

The sterilization process causes the nuts to expand due to moisture movement. Nuts contraction helps the kernel to be detached from the shell wall as a result of reduction in pressure. This process later accelerates nut cracking operation to release whole kernels.

d) Fruit Digestion

Digestion simply refers to the breaking down or rupturing of oil-bearing cells of palm fruits to release palm oil. The digester usually employed comprises of a steam-heated cylindrical container fixed with a principal rotating shaft that bears a number of stirrers or beater arms. Action of these rotating beater arms digests (pounds) the fruit.

Fruit digesting at high temperature decreases the palm oil viscosity; destroys the exocarp (outer covering) of the fruit, and enhances oil cells disruption which must have begun during the cooking phase. Meanwhile, iron contaminant with palm oil is common and is very high during digestion as a result of peak rate of metal tears and wears.

This contamination accelerates palm oil oxidation rate and subsequent results in rancidity of the palm oil [15].

e) Pressing (Palm Oil Extraction)

Two distinct methods could be used in extracting palm oil, namely: the dry and wet methods. The dry method employs mechanical presses.

The mechanical pressure is applied to the digested mash which aids in squeezing out the oil from the mixture of water, oil, nuts and fibre. The wet method makes use of hot water to seep out the oil. After this stage, a mixture of nut and fibre is left.

f) Clarification and Drying of Palm Oil

The reason for oil clarification is to segregate the oil from its ingrained, foreign materials. The fluid from the press is composed of fibrous material, cell debris, palm oil, water, and 'non-oily particles'. Due to high viscosity of the non-oily particles, hot water is added to the fluid in order to reduce its viscosity.

This treatment allows the dense solid particles to get to the bottom of the container whereas the less dense portion (i.e. palm oil) flows over the watery mix to the top when heat is supplied to disrupt the suspension. Addition of water is always in a ratio of 3:1. The diluted mix is screened to eliminate the bristly fibre. The screened mix is heated for 2 – 3 hours. This is later allowed to settle down by gravity in a large vessel so that the clear oil (palm oil), which is less dense than water, is collected into a tank (reception vessel). At this point, the clarified oil is re-boiled so that the moisture content could be reduced to 0.15 to 0.25 %. This prevents increase in free fatty acid content by autocatalytic hydrolysis. The oil can now be skimmed off. The wastewater is disposed into the nearby sludge pits for use as herbicide [15].

g) Storage of Oil

In a commercial palm oil mills, the filtered and dried palm oil is pumped to a reservoir (storage tank) before dispatch from the mill. The storage vessel is always maintained at about 50°C, because increase in temperature increases oil oxidation rate; and a low-pressure steam-heating coils or hot water is always used to abate fractionation and solidification.

h) Palm Nut Recovery and Drying

The residue from the press comprises of a mixture of palm nuts and fibre. In the large-scale nut recovery process, the nuts could be separated from the fibre using nut-fibre separator [27] or a depericarper. The nuts could be dried using any suitable method e.g. oven, solar dryer, etc. The nut could now be stored in silo between 6 – 8% moisture content wb [15].

i) Palm Nut Cracking and Kernel Separation

The dried nuts are cracked by employing centrifugal nut crackers to release whole kernels. The kernels are generally screened from the shells using a combination of hydrocyclones and winnowing, inclined draper, etc. The kernels obtained are conditioned (dried) to about 7.0 percent moisture content before packaging [28, 29, 15, 30, 31].

j) Extraction of Palm Kernel Oil

The palm kernels obtained are further crushed using mechanical crushing and pressing machine to obtain crude palm kernel oil (CPKO) and cake. The CPKO and cake are collected and stored in tanks and bags, respectively [27].

PRODUCTS OBTAINED FROM OIL PALM TREE

Many products are obtained from oil palm trees. These include palm oil, kernel oil, palm wine, kernel cake, fibre, wood plank, fatty alcohol and broom. Palm kernel oil can be used for making polish, glycerin, medicine, margarine, oil paint, candle, pomade, cosmetics, toothpaste, etc. [32, 33, 34, 35, 36]. Shell particles are generally used as domestic fuel for cooking, decorating houses in many rural communities and a source of coarse aggregate in light concrete mix. Other usages are as a key biomass material, replacing fossil fuel for steam power plant [37]. The kernel cake, on the other hand, is used in making livestock feed [33].

PRODUCTION OF PALM OIL IN NIGERIA BETWEEN 2010 – 2020

Nigeria is one of the five major producers of palm oil globally. The production capacity from 2010 to 2020 is presented graphically in Figure 6.

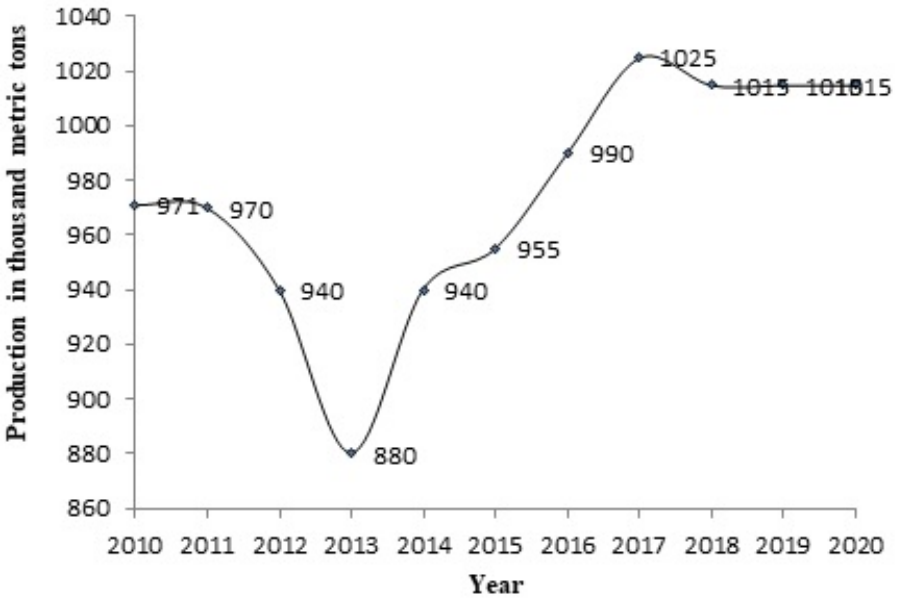

Fig. 6. Palm oil production capacity in Nigeria from 2010 to 2020.

From Figure 6, there was a drastic decrease in palm oil production from 971 – 880 thousand metric tons from 2010 to 2013, [38]. From 2013 – 2017, 16.4% increase was observed. Thereafter, decreased by 0.97% and remained unchanged in the last three years (1,015 thousand metric tons) as estimated till 2020 [38].

NUTRITIONAL COMPOSITION OF PALM OIL AND PALM KERNEL OIL

Palm oil has 99.9% crude fat, 0.1 mg Fe /kg and 9380 kcal gross energy / kg. It also has 11% vitamin E. Its fat generates all the calories. Its fatty acid is made of saturated-fatty acids (50%), mono-unsaturated fatty acids (40%) and poly-unsaturated fatty acids (10%). Its main unsaturated fat is palmitic acid. It also has smaller composition of stearic and linoleic acid but higher composition of oleic acid. The red pigment in the red palm oil contains antioxidants known as carotenoids. Human body is able to transform these carotenoids into vitamin A [36]. Palm kernel oil has higher saturated fats than palm oil. Besides, it is high in lauric acid, which is believed to raise blood cholesterol content, both as low-density lipoprotein (LDL-C) and high-density lipoprotein (HDL-C) (David, 2012). However, overall cholesterol concentration increase may be as a result of more of HDL-C than LDL-C. About 16.2% myristic acid (C14), 48.2% lauric acid (C12), 8.4% palmitic acid (C16), and 15.3% oleic acid (C18:1) form the main composition of fatty acid found in palm kernel oil.

The minor ones are 3.4% capric (C-10), 3.3% caprylic (C-8), and 2.5% stearic (C-18), all of which are the saturated fatty acids except oleic and linoleic [14, 39]. However, palm kernel oil is used commercially for cooking because it is more affordable than other oils and is stable at higher cooking temperatures [40].

RATIONALE FOR THE USE OF OIL PALM AND ITS DERIVATIVES IN THE DEVELOPMENT OF SUSTAINABLE FOOD AND ALLIED PRODUCTS

Need for the use of palm oil in many food applications cannot be overemphasized. About 72% of it is used in the food manufacturing industry. It is the most commonly demanded vegetable oil because it is economical to cultivate and its oil is characterized by neutral flavor. The demand is expected to be doubled by 2030 and tripled by 2050 [41]. Palm oil is semi solid at room temperature while other vegetable oils require hydrogenation (i.e. making them to be semi-solid). This process creates *trans-fatty* acids or *trans-fats* which raises cholesterol.. Moreover, it is odorless, and resistant to deterioration. It has an elongated shelf life. Palm oil is an inexpensive alternative for hydrogenated vegetable oils as found in many foods. It may be cumbersome to spot food products that contain palm oil or its derivatives. There are a lot of compounds that are made from palm oil fatty acids. Words such as glyc, palm, laur and stear could be used to identify these food products.

Sustainable Palm Oil

In recent years, the move towards sourcing for sustainable palm oil that is certified as organics by food industries has been encouraged by Roundtable on Sustainable Palm Oil (RSPO). Unfortunately, RSPO had been criticized for failing to sanction defaulting food industries in terms of non-compliance. Other approaches such as High Carbon Stock (HCS) and establishment like The Palm Oil Innovation Group (POIG) are known for standard higher than those projected by the RSPO [42].

Some Food Products Made From Palm Oil and its Functional Attributes

Some food products made from palm oil (as vegetable oil) as well as its functional attributes in food products formulation are presented in Table 1 [43].

Table 1.Food products from palm oil and its functional attributes

S/	Food products	Functional attributes
1.	Biscuits/Cookies	Palm oil shortens dough to give a melt-in-the-mouth and flaky texture.
2.	Bread	It enhances loaf volume and softness.
3.	Breakfast bars	It prevents melting during transportation.
4.	Butter/Margarine	Avoids product oxidation. Oil oxidation reduces oil quality and results in off flavour and smell. It also enhances consistency, texture and structure.
5.	Cake	It improves shelf life and texture of cake. It also makes cake to be softer, airier and increase volume and moistness.
6.	Cereal	It promotes crunchiness and freshness of cereal.
7.	Chocolate	It gives a smooth and shiny appearance to chocolate. It also prevents it from melting in warmer temperatures.
8.	Crackers	It enhances buttery flavour and texture.
9.	Crisps/ Doughnuts	It is used in frying potato chips/crisps/ doughnuts
10.	Dried nuts	It is used in roasting nuts.
11.	Canned soup	It preserves processed meals.
12.	Fast food	It promotes processed food taste, and makes it less greasy.
13.	Frozen meals	It is a natural food preservative. It prevents stickiness of meals.
14.	Ice cream	It increases the product melting point; and promotes a thicker consistency, smoothness and creaminess of the product.
15.	Infant formula	It gives a creamy texture to the product.
16.	Instant noodles	It is used for frying the product.
17.	Microwave popcorn	It gives a creamy flavour and aids the kernels to pop.
18.	Peanut butter	It binds nut oil with the nut solid part.
19.	Pizza bases	It averts dough from sticking and improves crispiness and texture of pizza base.
20.	Salad dressing	It is a natural anti-oxidant as a result of its stability and has reasonable content of vitamin E.
21.	Whipping cream	It is stable even at warmer temperatures.

CONCLUSIONS

Food is one of the basic necessities of life. Though, efforts have been made to enhance the quality and quantity of world food production and supplies, food insecurity still remains dominant in Nigeria, especially in the northern parts of the nation.

The rural communities are more prone to this menace. Thus, serious attention must be given in this regard.

However, with the availability of sustainable food products made from oil palm and its derivatives, the menace could be curtailed.

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RAZVOJ ODRŽIVIH PROIZVODA IZ ULJA PALME, JAČANJE NACIONALNE SIGURNOSTI HRANE: PREGLED

Assian Ubong Edet[1], Okoko Joseph Udoudo[1], Alonge Folarin Akindele[1], Udoumoh, Unwana Iniobong[1], Ehiomogue Precious[1]

[1]Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, Uyo, P. M. B. 1017, Akwa Ibom State, Nigeria

Apstrakt: Sve veća nesigurnost u proizvodnji hrane u Nigeriji primećuje se u gotovo svim delovima i oblastima nacionalne proizvodnje hrane. Čini se da je nesigurnost hrane globalni izazov koji ima mnogo povezanosti sa porastom potražnje za energijom, rastom broja stanovnika, klimatskim promenama i konkurencijom za zemljište, hranu i vodu. Seoska naselja su mnogo podložnija neredovnom snabdevanju hranom, niskom kvalitetu hrane, neuhranjenosti stanovništva i visokim cenama prehrambenih artikala, pa nekada i rasprostranjenom nedostatku hrane. Ova situacija je stvorila ozbiljnu zabrinutost za nacionalnu bezbednost sa aspekta hrane u Nigeriji.

Međutim, dobra dostupnost poljoprivrednih i prehrambenih proizvoda može ublažiti ovako opisane i predpostavljene pretnje u ovoj oblasti .
Dakle, u pokušaju da se opisana situacija promeni, ovaj rad predstavlja pregled razvoja nekih održivih proizvoda od palminog ulja za jačanje nacionalne prehrambene bezbednosti i sigurnosti u oblasti hrane .

Ukratko, dat je pregled osobina uljane palme, klasifikacija, trenutna i buduća mehanizacija u ovoj proizvodnji, pre svega prerada plodova od grozda do ekstrakcije sirovog palminog ulja i drugih dodatnih proizvoda, primena proizvoda; kao i kapacitet proizvodnje palminog ulja od 2010. do 2020. u Nigeriji.

Pored toga, u radu se analizira nutritivni sastav palminog ulja i ulja palminog jezgra, obrazlaže upotreba palminog ulja i njegovih derivata u razvoju održive hrane i sličnih drugih proizvoda. Zatim se razmatra koncept održivog korišćenja palminog ulja, neki prehrambeni proizvodi od palminog ulja i njegovi funkcionalni dodaci.
Posebno je naglašen razvoj nekih odabranih prehrambenih proizvoda sa palminim uljem kao jednim od glavnih sastojaka.

Ključne reči: *Uljana palma, održivi proizvodi, nacionalni, hrana, bezbednost*

Prijavljen: *Submitted*:	**29.07.2021.**
Ispravljen: *Revised*:	**03.02.2022.**
Prihvaćen: *Accepted*:	**10.02.2022.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLVII
Broj 1, 2022.
Strane: 34 – 42

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLVII
No. 1, 2022.
pp: 34 – 42

UDK: 633.34;631.01.017

Original scientific paper
Originalni naučni rad
doi: 10.5937/PoljTeh2201034A

INFLUENCE OF HEAT TREATMENT DURATION AND BIOLOGICAL COAGULANT TYPES ON THE MICROBIOLOGICAL PROPERTIES OF NIGERIAN SOFT SOY CHEESE

Abidemi Sunmola[1], Tosin Paul*[2], Nnaemeka Nwakuba[3], Ikechukwu Okosa[2]

[1]Department of Food Technology, Kaduna Polytechnic, P.M.B. 2021 Kaduna, Nigeria.
[2]Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, P.M.B. 7267 Umudike, Nigeria.
[3]Department of Agricultural and Bioresources Engineering, Federal University of Technology, P.M.B. 1526 Owerri, Nigeria.

Abstract: The study examines the microbiological properties of cheese from soy milk as influenced by heat treatment durations and biological coagulant types. The soy milk was pasteurized at 65°C and subjected to further heat treatment for 15, 20, and 25 minutes with the addition of coagulants (lime juice, tamarind pulp and moringa seed paste) to respective samples and allowed to cool for 30 minutes before pressing out the whey. The initial properties of raw soy milk were determined to serve as control and the nine produced soy cheese samples were determined using a 3x3 factorial treatment design. The microbiological properties of the cheese were determined using standard methods. Results obtained were analyzed statistically to determine the influence of heat treatment duration and coagulant sample. The microbial analysis revealed that there was Coliform in soy cheese samples which were all less than 1.0×10^2 cfu/g except in F_{15}, F_{20}, and E_{25} which had 4.2×10^2, 4.3×10^2, and 2.1×10^2 cfu/g which are within the permissible limit of consumption.

There were no Coliform bacteria in all samples except E_{15}, F_{20}, and F_{25} which had 1.6×10^3, 1.4×10^3, and 4.0×10^2 cfu/g, respectively which are also within the permissible limit of consumption.

*Corresponding Author. Email address: ptosin106@gmail.com

There was no yeast and mould growth on all the samples except E_{25} which is $<1.0x10^2$ cfu/g. This study is initiated to determine the effect of heat treatment and local coagulants on the microbial properties of Nigerian soft soy cheese. Hence, investigating the hygienic quality and safety of consuming the food product.

Keywords: *Soy cheese, lime, tamarind, moringa, microbial.*

INTORDUCTION

Heat treatment is the most widely used processing technology for microbial treatment in the dairy industry [7]. Some common methods such as heat treatment of fluid milk products for a predetermined time and temperature main objective is to destroy microorganisms and to ensure the milk is safe for consumption with a reasonable shelf life. Although there have been successes recorded in the use of chemicals such as calcium chloride (CaCl2) in the conversion of milk to cheese, it is necessary to use natural coagulants in the production of cheese. Natural coagulants are biological coagulants that have no consequence on the health of humans but serves as an additive. The coagulants are readily available in rural areas and are very cheap and highly effective in the coagulation of milk [7; 8]. These biological coagulants include moringa kernel cake, lime juice and tamarind pulp. The health benefits of lime include weight loss, skin care, improved digestion, relief from constipation, peptic ulcer, respiratory disorders, urinary disorders [9; 10]. [11] states that whole tamarind seed and kernels are also rich in protein (13-20%) and the seed coat is rich in fibre (20%) and tannins 20%. The local coagulants used in this study are as shown in Fig 1.

MATERIALS AND METHODS

The materials used for the study include soybean, moringa seed, lime, tamarind fruit, water, cooking pots, spoons, stirrer, stove, microwave, cheese knife, bowls, cheesecloth, mortar, pestle and blender.

(I) (II) (III)

Figure 1: (I) Lime fruit (II) Tamarind fruit, and (III) Moringa seed.

Sample collection and preparation

The soybean samples used for the study were obtained at Monday market, Kaduna. The ingredients, moringa seed, lime and tamarind fruit were obtained from the same market. The soy cheeses were produced at Crop Processing Laboratory, Food Technology Department, Kaduna Polytechnic, Nigeria. The samples and raw milk (control) were kept in sterile plastic containers and taken to the laboratory for microbial determination.

Instruments and reagents

The equipment used for the experiment are: laboratory oven dryer, microscope, autoclave, electric blender, flame photometer, calorimeter, incubator, fume cupboard, digital weighing balance, soxhlet apparatus, muffle furnace, burette, retort stand, funnel, conical flask, pipette, measuring cylinder, beaker spatula, the crucible, desiccators, soxhlet flask, filter paper, Petri dishes, and thermometer. The reagents used include phenolphthalein, formaldehyde, potassium sulphate, petroleum ether, potatoes dextrose, agar, Mackonkey agar, nutrient agar, ringer table, tartaric acid, and copper sulphate.

Preparation of coagulants

Moringa oleifera seeds were dehulled after which it was weighed and introduced into a pot to be toasted for 3 minutes. The seed was milled to powdered form using an electrical blender and then the oil was extracted by the manual method: by the use of hot water (little quantity) and the oil expressed manually. The seed paste obtained was used as a coagulant. The fresh lime was sorted, graded, washed, sliced, and squeezed to extract the juice, which was used as a coagulant for the production of cheese from soy milk. About 75 ml of the extracted juice was used in the production. The tamarind seed pod was sorted, washed and soaked in warm water for about six (6) hours and sifted to obtain the pulp. The pulp was then used as a coagulant for the production of cheese from soy milk. Also, 75 ml of the pulp was used in the production.

Microbial analysis

The standard method of [12] was employed. About 1 g of the different cheese samples was aseptically weighed using a weighing balance and carefully introduced into 9 ml of the sterile distilled water. This was shaken manually to have a homogenous suspension. 1ml of this was taken and introduced into the second tube, followed by series of dilutions up to 10^{-10} dilutions. 1ml was taken 10^{-4} dilution and introduced into sterile plates and modern agar (50 ºC) added by pour plate method using the following agar and incubation periods. Potato Dextrose Agar was used for the enumeration of mould and yeast in the sample. The plates were incubated at 30°C for 24 hours for yeast and 2 - 5 days for mould. Nutrient Agar was for the determination of total viable bacterial in the sample. The plates were incubated at 37 ºC for 24 - 48 hours. McConkey Agar was used for the enumeration of total Coliform organisms in the sample. The plates were incubated at 37°C for 24 to 48 hours.

Experimental procedure for soy cheese production

The soybeans were sorted, washed, and soaked in warm water for about six (6) hours before it was wet-milled and filtered. The raw milk was pasteurized in a microwave at 65°C for 10 minutes before the coagulants were added and subjected to further heat treatment for 15, 20, and 25 minutes to form the curds. It was then left to cool for 30 minutes and were later separated using a muslin cloth. The cheese was pressed and cut into desired sizes, packed and stored. A 3^2 factorial treatment design was applied to analyze the collated data and examine the experimental results. The test yielded about nine (9) experimental runs for the soy cheese sample. The results were analyzed with a completely randomized design with 2 replicates. All data were subjected to variance analyses using SPSS 20.0 statistic program. Table 1 shows the codes for cheese production from soy milk. The volume of milk used for the milk sample is 1000 ml per run. The experimental layout for the study is shown in Table 2.

Table 1. Layout for production of cheese produced from Soy milk

No. of runs	Codes	Meaning
1	D_{15}	Lime coagulated Soy cheese for 15 minutes Heat Treatment duration
2	D_{20}	Lime coagulated Soy cheese for 20 minutes Heat Treatment duration
3	D_{25}	Lime coagulated Soy cheese for 25 minutes Heat Treatment duration
4	E_{15}	Tamarind pulp coagulated Soy cheese for 15 minutes Heat Treatment duration
5	E_{20}	Tamarind pulp coagulated Soy cheese for 20 minutes Heat Treatment duration
6	E_{25}	Tamarind pulp coagulated Soy cheese for 25 minutes Heat Treatment duration
7	F_{15}	Moringa seed paste coagulated Soy cheese for 15 minutes Heat Treatment duration
8	F_{20}	Moringa seed paste coagulated Soy cheese for 20 minutes Heat Treatment duration
9	F_{25}	Moringa seed paste coagulated Soy cheese for 25 minutes Heat Treatment duration

Table 2. Layout of experimental design

	Coded Values		
	High	Middle	Low
Parameters	1	0	-1
Heat Treatment Duration	25	20	15
Coagulants	Lime (D)	Tamarind pulp (E)	Moringa seed Paste (F)

Note: -1, 0, and 1 signify: low, mid and high ranges, respectively.

DISCUSSION OF RESULTS

The results of the microbiological properties of the cheese produced from soy milk when subjected to various heat treatment durations and different biological coagulants show the mesophilic aerobic bacteria (total plate count) as presented in Tables 3, 4, and 5. The result in Table 3 indicates the presence of colonies of variation between $<1.0x10^2$ and 4.3×10^2 cfu/g which is in line with the findings of [13].
The raw milk shows no colonies which may be due to the heat treatment applied but the main products have colonies that are negligible $<1.0 \times 10^2$.
However, this is within the acceptable range for ready eat the food of $<10^5$ cfu/g as reported by [14 and 15]. The results showed the influence of heat treatment duration and coagulant types on the reduction in the total colonies counted. F_{15} and F_{20} have the highest colonies of 4.2×10^2 and 4.3×10^2 cfu/g and E_{25} has 2.1×10^2 cfu/g, this is similar to results obtained by [7]. The overall results showed that the coagulants and heat treatment reduced the mesophilic aerobic bacteria.

Table 3. Mean value for enumeration of mesophilic aerobic bacteria (Total Plate Count) of cheese produced from soy milk at different heat treatment durations and different coagulants

Sample Code	Cfu/g/ml	Coded
	$<1.0x10^2$	-1
D_{15}		
E_{15}	$<1.0x10^2$	0
F_{15}	$4.2\ x10^2$	1
D_{20}	$<1.0x10^2$	-1
E_{20}	$<1.0x10^2$	0
F_{20}	$4.3\ x10^2$	1
D_{25}	$<1.0x10^2$	-1
E_{25}	$2.1\ x10^2$	0
F_{25}	$<1.0x10^2$	1
Control	Nil	-1

D = Lime coagulant soy cheese, E = Tamarind coagulant soy cheese, F= Moringa coagulant soy cheese, 15 = 15 minutes heat treatment duration, 20 = 20 minutes Heat treatment duration, 25 = 25 minutes heat treatment duration.

The result in Table 4 shows that there was a reduction in the coliform bacteria which may be as a result of the heat treatment applied, [16] also reported a similar reduction in coliform bacteria. At 15 minutes only E_{15} has Coliform bacteria $1.6x10^3$ cfu/g, F_{20} has Coliform of 1.4×10^2 cfu/g whereas at 25 minutes F only has Coliform bacteria. The cheese when subjected to high temperature during frying will destroy the Coliform bacteria present. The control has coliform bacteria when subjected to heat treatment with the inclusion of coagulants. However, the result indicated that the samples are within the acceptable standard required for cheese consumption according to [4 and 17].

Table 4. Mean values for coliform bacteria of cheese produced from soy milk at different heat treatment duration and different coagulants

Sample Code	cfu/g/ml	Coded
D_{15}	Nil	-1
E_{15}	$1.6x10^3$	0
F_{15}	Nil	1
D_{20}	Nil	-1
E_{20}	Nil	0
F_{20}	$1.4 x10^3$	1
D_{25}	Nil	-1
E_{25}	Nil	0
F_{25}	$4.0 x10^2$	1
Control	$1.3 x10^2$	-1

D = Lime coagulant soy cheese, E = Tamarind coagulant soy cheese, F= Moringa coagulant soy cheese, 15 = 15 minutes heat treatment duration, 20 = 20 minutes Heat treatment duration, 25 = 25 minutes heat treatment duration.

The results in Table 5 showed that there was no yeast and mould found at 15 minutes heat treatment duration for D, E, and F. At 20 minutes there was no yeast and mould found in the samples of D, E and F. But sample E and only showed the presence of yeast and mould at 25 minutes at $<1.0 \times 10^2$ cfu/g, this result agrees with the finding of [13] which is still within the permissible level for cheese consumption (3.0×10^3 cfu/g) according to [4].

Table 5. Mean values for enumeration of yeasts and moulds of cheese produced from soy milk at different heat treatment duration and different coagulants

Sample Code	cfu/g	Coded
D_{15}	Nil	-1
E_{15}	Nil	0
F_{15}	Nil	1
D_{20}	Nil	-1
E_{20}	Nil	0
F_{20}	Nil	1
D_{25}	Nil	-1
E_{25}	$<1.0x10^2$	0
F_{25}	Nil	1
Control	$<1.0x10^2$	-1

D = Lime coagulant soy cheese, E = Tamarind coagulant soy cheese, F= Moringa coagulant soy cheese, 15 = 15 minutes heat treatment duration, 20 = 20 minutes Heat treatment duration, 25 = 25 minutes heat treatment duration.

CONCLUSION

The following conclusions were drawn from the study:

I. The microbiological analysis revealed that the soy cheese samples were all fit for consumption at all the HTD.
II. The microbial analysis revealed that there was Coliform in soy cheese samples which were all less than 1.0 x 10^2 cfu/g except in F_{15}, F_{20} and E_{25} which had 4.2 × 10^2, 4.3 × 10^2 and 2.1 × 10^2 cfu/g which are within the permissible limit of consumption.
III. There were no Coliform bacteria in all samples except E_{15}, F_{20} and F_{25} which had 1.6x10^3, 1.4 x10^3 and 4.0 x10^2 cfu/g respectively which are also within the permissible limit of consumption.
IV. There was no yeast and mould growth on all the samples except E_{25} which is <1.0x10^2 cfu/g which is within the permissible limit of consumption.

RECOMMENDATION

Nigerian soft soy cheese made with local coagulants should therefore be recommended for consumption. Further experimental tests could be carried out on the effect of heat treatment and local coagulants on the sensory, mineral and proximate properties of the sample.

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UTICAJ TRAJANJA TOPLOTNE OBRADE I VRSTE BIOLOŠKIH KOAGULANTA NA MIKROBIOLOŠKA SVOJSTVA NIGERIJSKOG MEKOG SIRA OD SOJE

Abidemi Sunmola[1], Tosin Paul[2*], Nnaemeka Nwakuba[3], Ikechukwu Okosa[2]

[1]Department of Food Technology, Kaduna Polytechnic, P.M.B. 2021 Kaduna, Nigeria.
[2]Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, P.M.B. 7267 Umudike, Nigeria.
[3]Department of Agricultural and Bioresources Engineering, Federal University of Technology, P.M.B. 1526 Owerri, Nigeria.

Apstrakt: U radu se ispituju mikrobiološka svojstva sira (tofu) od sojinog mleka, pod uticajem dužine trajanja termičke obrade i vrste bioloških koagulanata.

Sojino mleko je pasterizovano na 65°C i podvrgnuto daljoj toplotnoj obradi po intervalima u trajanju od 15, 20 i 25 minuta uz dodavanje bioloških koagulanata (sok limete, pulpa tamarinda i pasta od semena moringe) odgovarajućim uzorcima i ostavljeno 30 minuta da se ohladi. Inicijalna svojstva sirovog sojinog mleka su određena kao kontrola, a devet proizvedenih uzoraka sojinog sira je određeno korišćenjem ogleda 3x3 sa dizajniranim faktorskim tretmanom .

Mikrobiološke osobine sira su određene standardnim metodama. Dobijeni rezultati su statistički analizirani da bi se utvrdio uticaj trajanja termičke obrade i uticaja primenjenog biološkog koagulansa.

Mikrobiološka analiza je pokazala da u uzorcima sojinog sira postoji Coliform bakterija sa vrednostima koje su manje od $1.0x10^2$ cfu/g, osim uzoraka F_{15}, F_{20}, and E_{25} koji imaju: 4.2×10^2, 4.3×10^2, i 2.1×10^2 cfu/g, a koji su u dozvoljenim granicama za potrošnju proizvoda.

U svim uzorcima nije bilo Coliform bakterija, osim uzoraka E15, F20 i F25 koji su imali $1.6x10^3$, $1.4x10^3$ i $4.0x10^2$ cfu/g, koji su takođe u granicama dozvoljene potrošnje.

Nije registrovan porast kvasca i plesni (buđ) na svim uzorcima osim uzorka E25 gde su ove vrednosti ranga $<1.0x10^2$ cfu/g.

Ova studija je pokrenuta da se utvrdi efekat toplotne obrade i lokalnih bioloških koagulanata na mikrobiološke osobine nigerijskog mekog sira (tofu) od soje .

Dakle, prikazano je ispitivanje higijenskog kvaliteta i bezbednosti konzumiranja prehrambenog proizvoda.

Ključne reči: *soja-sir, limeta, tamarind, moringa, mikrobiološko.*

Prijavljen: *Submitted*:	**16.07.2021.**
Ispravljen: *Revised*:	**10.12.2021.**
Prihvaćen: *Accepted*:	**15.01.2022.**

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

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

UDK: 664.78.01:631.21

Original scientific paper
Originalni naučni rad
doi: 10.5937/PoljTeh2201053B

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

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

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

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

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

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

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

INTRODUCTION

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

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

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

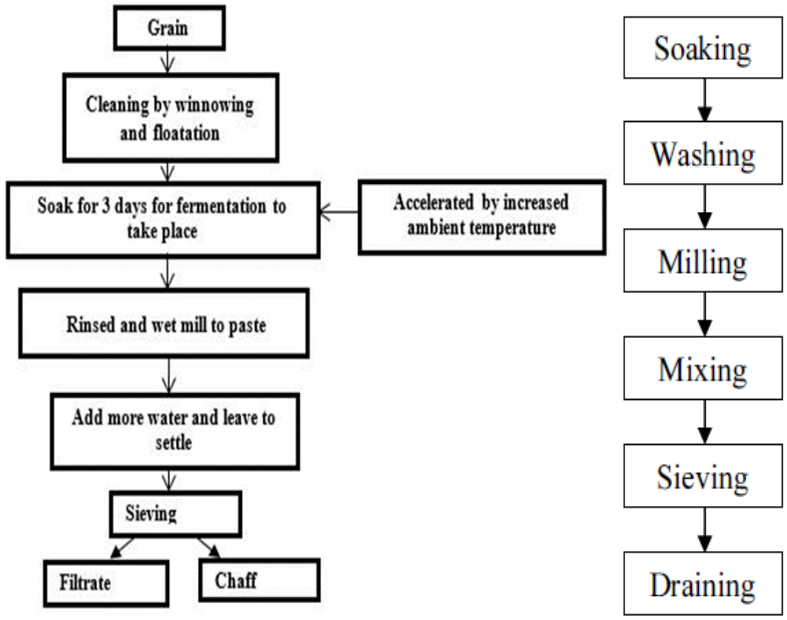

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Fig.1. Unit Operations' sequence in grain slurry processing
as described by [3] and [1] respectively

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

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

MATERIAL AND METHODS

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

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

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

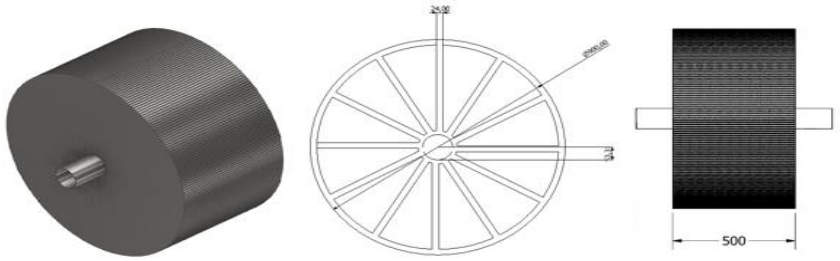

Figure 2: Rotary vacuum drum filter

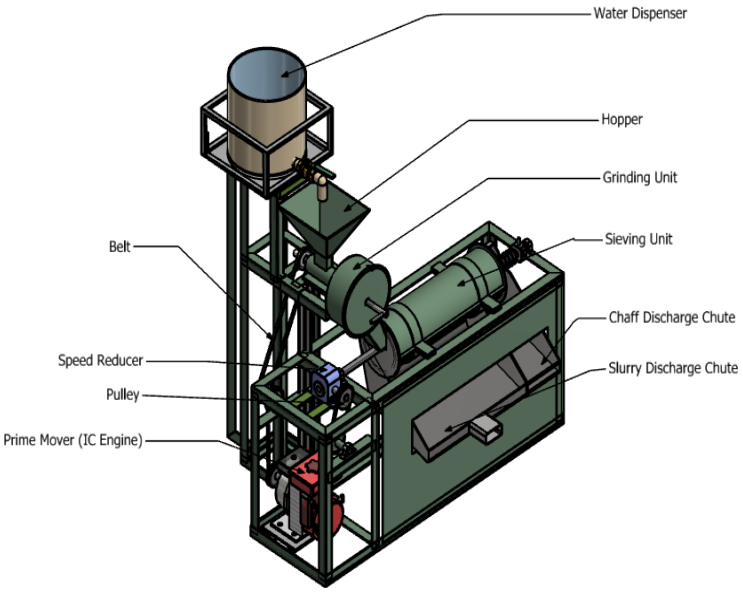

Figure 3. Slurry food milling and sieving machine by [8]

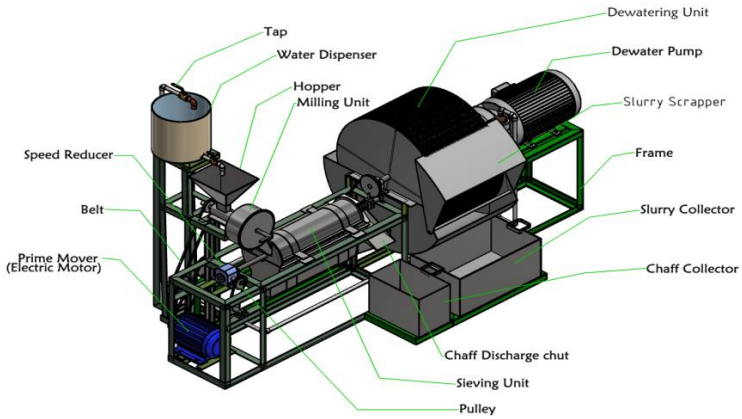

Figure 4. Grain slurry food milling-sieving-dewatering machine.

Design Analysis of the Rotary Vacuum Drum Filter

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

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

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

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

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

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

$$C = \frac{D_1+D_2}{2} + D_1 \frac{D_1+D_2}{2} + D_1 \tag{2}$$

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

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

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

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

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

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

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

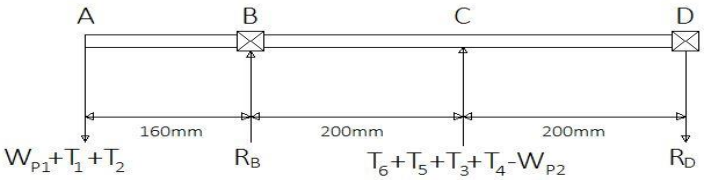

Figure 5. Force diagram of the primary shaft

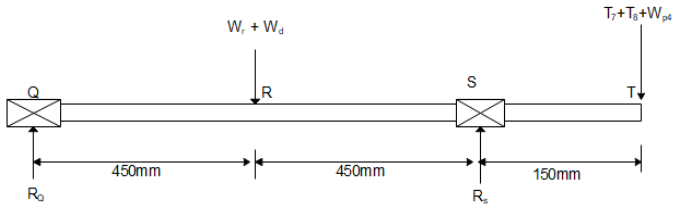

Figure 6. Force diagram of the drum shaft

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\Delta \mathrm{p_t} = \frac{4\sigma_\mathrm{l} \cos \theta_\mathrm{l}}{\mathrm{D_p}} \tag{16}$$

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

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

Performance Evaluation Procedure

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

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

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

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

$$TP = \frac{20}{t} \quad (19)$$

$$\eta = \frac{100M_f}{17+M_cM_f} \quad (20)$$

RESULTS AND DISCUSSION

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

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

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

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

CONCLUSIONS

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

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

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

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

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

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

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

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

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

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

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

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLVII
Broj 1, 2022.
Strane 56 – 78

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLVII
No. 1, 2022.
pp: 56 – 78

UDK:631.372:632.51:632.931.5

Review paper
Pregledni rad
doi: 10.5937/PoljTeh2201066S

INTEGRATED PLASTIC MULCH LAYING MACHINE -A VIABLE TECHNOLOGY FOR SUSTAINABLE AGRICULTURAL PRODUCTION

Shoaib Amin[1], Jagvir Dixit*[1], M. Muzamil[1]

[1]Division of Farm Machinery and Power Engineering, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, India

Abstract: A tractor drawn mulch laying machine was developed in order to integrate the operations and fix the anomalies in terms of labour associated with conventional mulch laying operations. The prototype integrates the operations of bed making, drip line laying, mulch laying, mulch covering and punching hole on mulch in one pass. The developed prototype was evaluated at three-levels of forward speed (3.0, 5.0, 7.0 kmh^{-1}), two-levels of bed width (76.2, 91.4 cm) and two-levels of dibbling hole spacing (15.2, 20.3 cm). The results of evaluation experiment for the developed machine showed that the draft requirement decreased with the increase in forward speed (3.0 to 7.0 kmh^{-1}), bed width (76.2 to 91.4 cm) and dibbling hole spacing (15.2 to 20.3 cm). Field efficiency increased with increase in forward speed, bed width and spacing of dibbling holes. Although at low speed (3.0 kmh^{-1}), the actual field capacity and field efficiency decreased about 57% and 5.0%, respectively while draft increased about 36 %, compared to the speed of 7.0 kmh^{-1}. However, at a speed of 3.0 kmh^{-1}, the mulch damage, un-covered mulch percentage and missing of dibbling hole decreased about 65%, 64% and 7.0 %, respectively.
The standardized value of draft requirement, effective filed capacity and field efficiency were observed as 63.27 kp, 0.40 $ha.h^{-1}$ and 72.7% while as percentage uncovered mulch, percentage mulch damage and percentage missing number of holes were as 3.1 %, 3.4%, 6.25%, respectively.

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

The man-hour requirement and cost of mulching operation with developed machine reduced about 97 % and 75 % as compared to conventional method of mulch laying. Therefore, the study recommends using the developed machine to install a raised-bed, laying of plastic mulch and drip irrigation pipes on the bed and making dibbling hole for vegetable seedling transplanting at a speed of 3 kmh^{-1} achieved the better efficiency.

***Key words**: Mulch laying machine, draft requirement, field efficiency, mulch damage, bed width, hole spacing, uncovered mulch*

INTRODUCTION

Agriculture plays a vital role in India's economy, 54.6% of the population is engaged in agriculture and allied activities and it contributes 17% to country's GDP [1], for the year 2018-19. Steps have been taken to improve soil fertility, farm mechanization, irrigation, protected cultivation including plasticulture [2]. The green revolution with its emphasis on high yielding variety seeds, fertilizers, pesticides and better methods of farming, swept like a wave into the Indian countryside. It turned us from being deficient in food grains to being self-sufficient [3]. But the increase in agricultural yield has to keep pace with the growing population that can be attained by mechanization in agriculture. The present agricultural production is insufficient to mitigate the requirement of growing population due to the limited scope of increase in cultivable area and low level of mechanization [4]. Mechanization in agriculture has enhanced production and productivity of agricultural commodities through timeliness of operation, better management of inputs and reduction of post harvest losses [5] in the country. Mechanization enhances productivity of crop by 15% and reduces cost of crop production by 20% [4,5]. Indian farms are irrigated primarily by monsoons as three-fifth of the land is irrigated directly by rainfall. To irrigate these lands, India receives three fourth of its rains, in just four months of the year [6]. As per estimates by the year 2025 about one-third of India would be under absolute water scarce condition [2]

Therefore, the technique of creating micro-environment for plants in agriculture is at significant demand so as to increase the produce at the cost of consuming lesser amount of resources which can be achieved by plastic mulching in agricultural fields [7].

Mulch cover can play a neutral role or reduce the risk of insect pest attack to crop plants by preventing direct movement of insects from soil to plants. Plastic mulches are primarily used to protect seedlings and shoots through insulation and prevent evaporation, thus maintaining or slightly increasing soil temperature and humidity [8]. Furthermore, the application of plastic covers is known to reduce weed and pest pressure [9]. Often reported benefits are minimization of the development time for seed and fruit, yield increase, the prevention of soil erosion and weed growth and consequently reduction of herbicide and fertilizer use [10,11].

These prospects have made plastic films an upcoming technology, now a days making up by far the largest proportion of covered agricultural surface in Europe (4270 km^2), an area four times larger than that covered by greenhouses and six times that of low tunnels [12]. Plastic films are laid before crop planting or transplanting.

This includes preparation of seed bed, spread mulch film and anchoring of edges of film. Raised seed bed has to be prepared for plastic mulching [13].

Two persons are required for laying the plastic over the soil bed, while one more person behind them to shovel the soil onto the edges of the mulch. These operations when done by manually become very time consuming, labour intensive, tedious and costly.

Plastic mulching by conventional method requires more human labour, more time and more cost of operation [13]. A number of automatic mulch laying machines have been developed but they are either not available in India or their use is limited to only large-scale farmers due to high capital investment. The existing machines for plastic mulching operations have the snag of using separate bed-maker. They can lay down the plastic mulches for fixed bed width only and they don't have the dibbling tool to make holes on the mulch moreover, their cost is very high. Hence, a new tractor drawn plastic mulch laying machine along with integral part as drip laying and mulch laying tool with soil covering on the edges and dibbling device was developed .

MATERIAL AND METHODS

The tractor operated plastic mulch laying machine was developed with aims to form wide raised bed, laying plastic mulch on bed surface, as well as laying lateral drip irrigation tapes/pipes on the surface of the raised-beds and punches hole in the plastic mulch for transplanting of vegetable seedlings.

Design Considerations

The development of integrated tractor drawn mulch laying machine was carried out by considering the agronomic and machine parameters. The design of machine components was based on the principles of operations and following functional requirements:

- To make two ridges on both sides so as to raise the soil in bed shape
- Laying of the mulch film on the well-prepared bed
- Unrolling the drip tape or drip roll on the bed surface formed by the machine
- To stretch the laid mulch film on the bed with the help of a press wheel
- Provision of earthing up unit to cover edges of mulch film with soil from both side
- Provision for dibbling unit to make holes on mulch at required spacing
- The hitching of machine should be compatible with tractors of different makes and models
- The adjustment of bed size, mulch size, hole spacing and covering device should be easy

The conceptual model of proposed machine was developed using Auto-CAD 20.2.1 software package of Autodesk 2018. The conceptual model was prepared in 3D version of the software (Fig. 1) with rendering of 720p and CAD-walk of 360^{o} for walk around view.

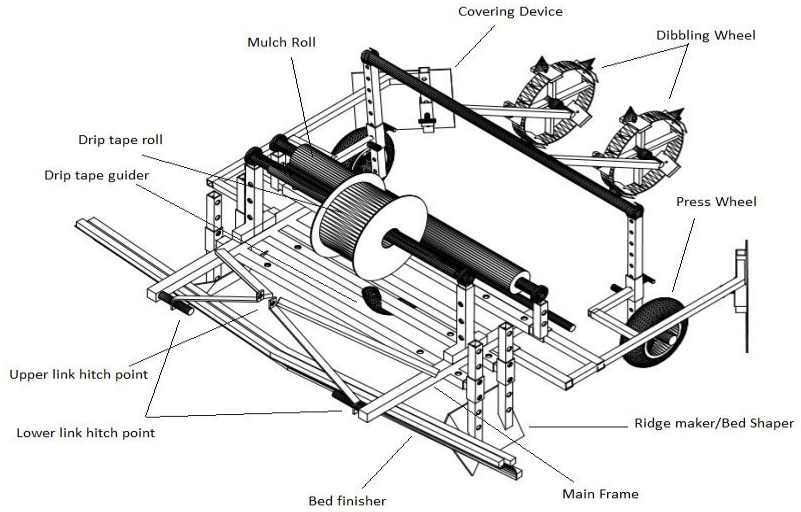


Fig. 1. Conceptual view of plastic mulch laying machine

The tractor operated plastic mulch laying machine was designed, developed and fabricated at the Division of Farm Machinery and Power Engineering, S.K. University of Agricultural Sciences and Technology, Srinagar (India). The integrated tractor drawn mulch laying machine consisted of a frame, hitching unit, bed finisher, ridge maker/bed shaper, mulch laying unit (mulch holder + mulch guider), drip laying unit (drip holder + drip Guider), press wheels, earthing up unit and dibbling unit.

Main frame

The main frame was made up of galvanized iron square hollow pipe of 14-gauge. The frame (Fig. 2) was made rigid so as to support all the other components of the machine and to withstand different types of load. The length of the frame was 915 mm. and the height of main frame was kept at 813 mm above the ground level. All parts of machine-like hitching unit, press wheels, mulch laying unit and earthing up unit were attached to the main frame. The hitching unit and the bed finisher used to remove the extra material to scrap from the bed are an integral part of the main frame. There was a small hollow round pipe of size 152 mm with outer diameter (OD) 25mm welded to the main frame which serves as a drip guider.

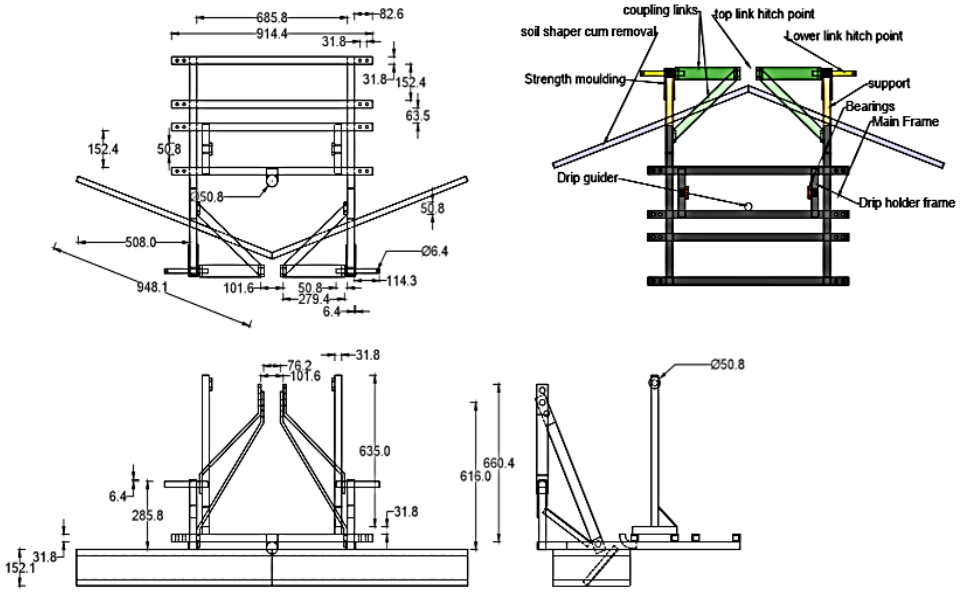


Fig. 2 Annotated Diagram of Main Frame

Mulch laying unit

Mulch laying unit was for laying the mulch film on the bed. The mulch laying unit was fabricated using two galvanized iron square hollow pipes (254 × 32 mm), each was fixed to the supporting frame at one end and other end to the bearing.

A shaft (mulch holder) was provided in between the two parallel bearings so that it could be used to unroll the plastic film. The plastic film was fitted on the shaft by removing it from bearing at one side or on both sides by removing bolt and nut of mulch holder cum locking device. This unit was supported by a frame.

The height of the shaft of mulch laying unit was kept at 240 mm above the bed finisher. The length of mulch laying unit shaft was 1410 mm. A provision has been kept to use different size of mulch film.

Support frame

The support frame (Fig. 3) contains the assembly for pressing wheels, mulch holder and covering device holder. The mulch guider is also attached to the supporting frame. The mulch guider is made up of 8 mm mild steel solid rod with three bends to avoid any mulch damage by sharp ends, the three bends are provided at an angle of 120^o, 120^o and 135^o and the length of mulch guider between different angles is 104, 150, 623 and 72 mm, respectively. The support frame is attached to the main frame by two galvanized iron hollow square of size 457 x 25 mm which are further welded to the mild steel square of same size as used for main frame, having length of 279 mm.

Tyre holder are also attached to the support frame with mild steel axle. The mulch roll holder welded to the supporting frame and has the height of 254 mm from the supporting frame.

At the rear side of the frame, covering device holder was mounted to the aligned part of the supporting frame with the help of nut-bolt and the angle to which the covering device holder was mounted on support frame.

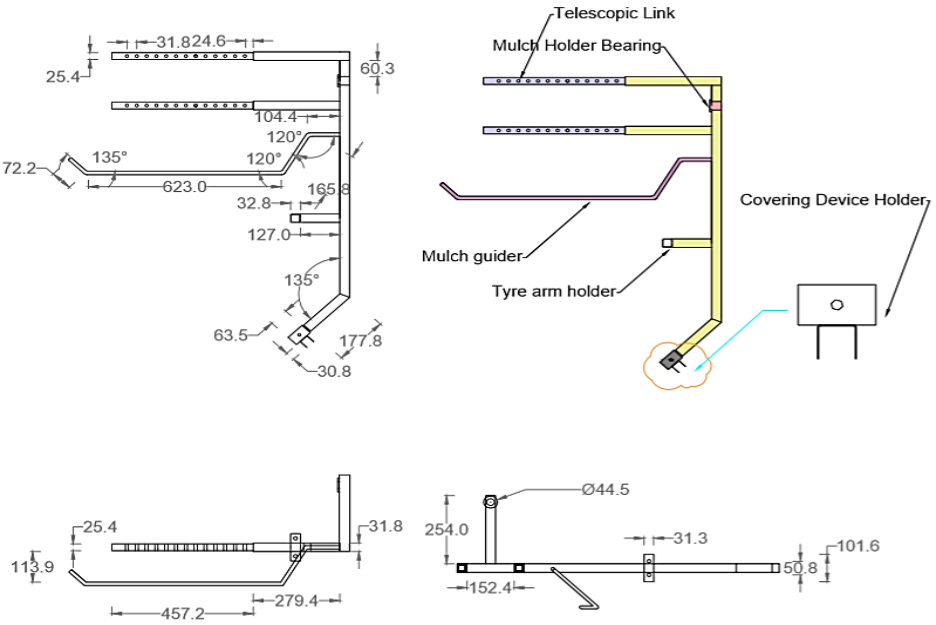


Fig 3. Annotated Diagram of Support Frame

Press wheel

The two press wheels were provided for compacting laid mulch film edges on the bed to protect it from the wind and a mulch roller was provided on its front (Fig. 4). The adjustable pneumatic rubber wheels of size 3.50-8″ 4PR have been used in the machine for pressing the plastic film edges to the ground and were mounted on the support frame. The press wheels were fitted on axle of 101 x 38 mm called the tyre adjusting arm. The center to center distance of wheels was kept same as that of bed outer edge.

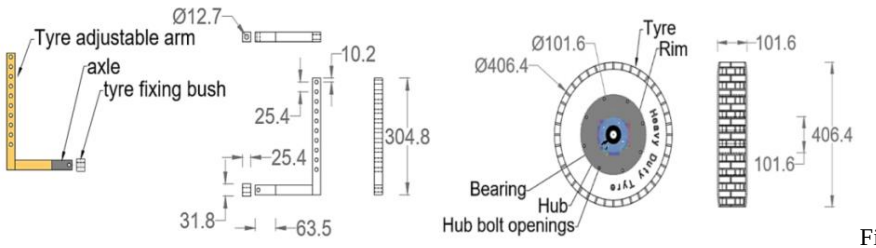


Fig 4. Annotated diagram of press wheels and its assembly

Earthing up unit (soil covering unit)

The function of the soil covering unit was to cover the mulch edges so as to fix the laid mulch in its position. Two earthing up units (Fig. 5) were provided on both sides at an angle of 60º to the direction of travel so as to increase the sweep area to deposit more soil on mulch edges.

It was mounted just behind the press wheels. The cross section of earthing up unit was designed, in such a way that it cuts soil up to a desired depth and properly covers the plastic film. It digs the soil up to a depth of about 5-7 cm and gathers soil and cover about 20 cm length of plastic film.

Drip laying unit

The drip laying unit consisted of drip roll holder and drip guider both of which were made of round hollow pipe. The drip guider consisted of a small hollow round bended pipe of size 152 mm with ϕ25 mm welded to the female telescopic arm of the main frame. The drip roll rotates on a shaft of size 635 mm x 25 mm. The drip roll unrolls on the shaft and drip went through drip guider and lays the drip on the bed. The drip roll rotates on the shaft plugged in ball bearings on both sides on two vertical square pipes of size 635 mm x 32 mm welded to the main frame.

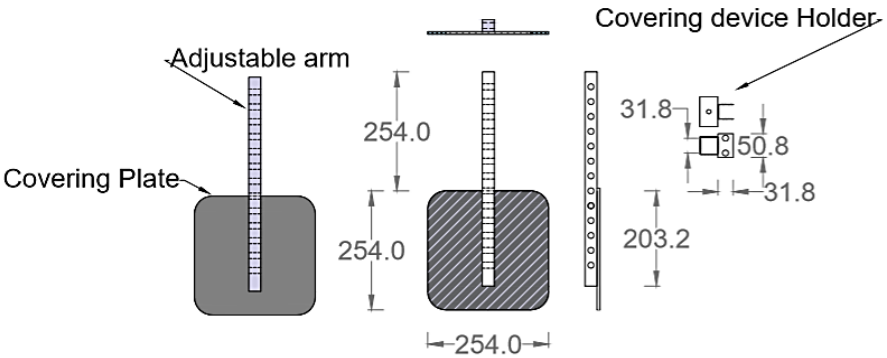


Fig. 5. Annotated Diagram of Soil Covering Unit

Ridge maker/bed shaper

The ridge making unit (Fig. 6) consisted of the male telescopic square iron of size 444 x 25 mm welded at right angle to the bed shaper tool guider of size 114mm x 32 mm, bended MS sheet welded to two MS square pipes and the guider provided with two holes so as to adjust the bed shaper with the help of two nut bolts. The main function of the bed maker was to form a bed on which plastic mulch was laid out.

Bed Finisher

The proper shape of the bed was maintained by bed finisher by removing the extra soil. It was made of mild steel sheet supported by angle iron of size (948 x 2) mm x 25 mm and the height of the bed shaper was 152 mm.

The two pieces were welded at an angle of 130^{o} so that soil would sway sideward. The bed finisher is welded to the main frame thus remaining an undetectable part of the main frame.

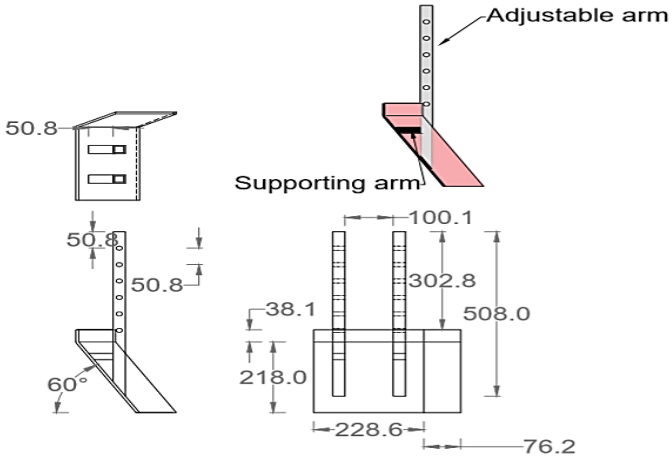


Fig. 6. Annotated Diagram of Bed Maker

Dibbling Device

The dibbling device (Fig. 7) was made using a circular wheel of 457mm ϕ and dibbling cones were provided on the periphery of wheel. The spokes were welded to inner side of ring on one side and other side is welded on round hollow pipe with of length 50 mm and ϕ38 mm. The ring rotates on an axle within the hollow pipe. The axle was made of round hollow pipe of ϕ 25 mm welded to an arm of square iron having length of 445 mm, breath 25 mm and thickness of 2 mm. To fix the location of ring on axle a bush of length 19 mm and ϕ 32 mm was welded to free end of axle. An arm is further welded to a hollow pipe of ϕ 32 mm and length 102 mm so as to allow the easy adjusting of dibbling device location by easy access of the device on the round pipe of ϕ 25 mm.

The details of the specification of developed machine are given in Table 1 and actual fabricated view of developed tractor operated integrated plastic mulch laying machine is shown in Fig. 8.

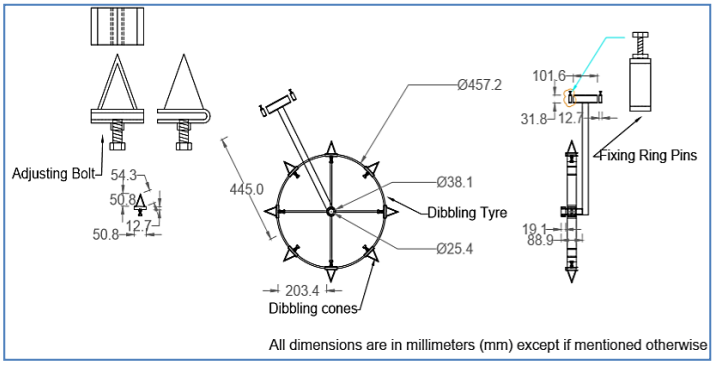


Fig. 7. Detailed Diagram of Dibbling Unit

Table 1. Specification of the developed integrated tractor drawn mulch laying machine

S.No.	Particulars	Units	Specification
1.	Source of power	hp	Tractor (>30 hp)
2.	Overall dimensions (l x b x h)	mm	4780 x 1700 x 812
3.	No and size of Press Wheel	in	two, 84 PR
4.	No and Soil Covering Device Size	mm^2	two, 254
5.	Main Frame Size (length)	mm	915
6.	Soil scraper / Soil shaper Size Angle	Mm/^{o}	1896.2 / 135 ^{o}
7.	No. and Bed Maker (BM) Size (l x h)	mm	Two, 444 x 114
8.	No. and Mulch Holder (MH) Size	mm	One, 1410
9.	No. and Drip Holder (DH) Size	mm	one, 635
10.	No. and Mulch Guider (MG) Size Angle	Mm/^{o}	Two, 871 120 & 135 ^{o}
11.	No. and Supporting frame (SF) Size	mm	Two, 279
12.	No. and Dibbling Device (DD) Size	mm	Two, ϕ 457
13.	Mass of machine	kg	82

Fig. 8. An overview of final assembled prototype

Working Principle of Tractor Drawn Integrated Mulch Laying Machine

The main working principle of the tractor drawn integrated mulch laying machine is by the virtue of the forward motion of machine from the tractor's (prime mover) pull via its drawbar. The machine is mounted type therefore it is subjected to the hydraulic system of the tractor. Initially the plastic mulch is fixed by placing an adequate amount of soil on the mulch passed under press wheels. As the tractor pulls machine at the depth set by the hydraulics, the scraper (bed finisher) fixed on the front of the machine removes the extra material. Bed shaper at the depth fixed by hydraulics in the soil operated by secondary tillage implement form ridges on both sides and gives the bed shape to the soil passing through it. The drip tape roll adjusted on the machine unrolls and passes through drip guider and lays itself on the bed shaped soil now the mulch roll unrolls and is laid on the soil shaped as bed. The mulch passes under mulch guider to avoid it from being shrinked due to wind and then mulch is passes under press wheels to keep it spreaded on the soil. The press wheels run over the mulch right at the sections of the soil where ridge has been formed and then soil covering devices come into action to cover the mulch by diverting the soil on the edges of the mulch. Finally, the dibbling wheels serve their purpose to make holes on the mulch laid at the spacing required. At the end of row mulch is cut manually and soil is placed on the free end of laid mulch to avoid its displacement.

Field evaluation

This study was carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India (latitude: 34° 08' 56 " N, longitude: 74° 52' 22" E) on sandy loam soil during 2019-20 (Fig. 9). A rectangular field of size 33 x 12 m was taken for the evaluation of the developed prototype.

Before the evaluation of prototype under actual field conditions, the soil texture, soil moisture content and soil hardness was measured at seven randomly selected locations in the experimental field.

The soil texture was sandy loam with clay 7-20%, sand 43-52% and silt 15%. The average moisture content of soil surface layer (0-30 cm) was determined and found to be 12.3% (wb). The hardness of soil was measured at 16 cm and 30 cm depths as the soil working tool of the machine was made to penetrate the soil in the range of 16-30 cm (Table 2). The average hardness of soil at the depth of 16 cm and 30 cm were 1486 kPa and 2659 kPa, respectively (Table 2).

Experimental Design

The experiment was established as factorial design (unbalanced) in three replicates, with three levels of forward speed (3,5 and 7 km/h), two levels of bed width (76.2 and 91.4 cm) and two levels of hole spacing (15 and 20 cm). The speed range for the developed prototype was selected on the basis of fact that farm machinery achieves higher efficiency at the speed range of 4-6 kmh^{-1} [14], the three levels of the speed range were above, below and in the range at which maximum field efficiency is achieved. The most common bed width being used in the vegetables is 80-90 cm [15]. The two test levels of the bed width were selected accordingly.

The test spacing of the plants (dibbling hole) were kept at 15 cm and 20 cm which are being extensively used in the mulching fields [16]. The plant-plant spacing was adjustable in the developed prototype. Experimental details and treatment combinations presented in Table 3 and Table 4, respectively.

Table 2. Measurements of the field parameters

			Soil Hardness (kPa)	
S.No.	Soil type	Soil Moisture, w.b. (%)	At 16 cm depth	At 30 cm depth
1	Sandy Loam	10.9	1518	2753
2	Sandy Loam	11.9	1511	2729
3	Sandy Loam	12.3	1507	2667
4	Sandy Loam	12.4	1503	2666
5	Sandy Loam	12.5	1470	2659
6	Sandy Loam	13.1	1466	2629
7	Sandy Loam	13.3	1459	2582
	Average	12.3	1486	2659
	Max.	13.3	1518	2753
	Min.	10.9	1459	2582
	S. D	0.008	24.555	58.554
	S. E	0.003	9.28	22.131

Table 3. Plan of the experiment

Parameters	Levels	Values	Responses
Forward speed (S)	3	$(S_1) = 3$ kmh^{-1} $(S_2) = 5$ kmh^{-1} $(S_3) = 7$ kmh^{-1}	• Draft requirement (kp). • Effective field capacity (hah^{-1}) • Uncovered mulch edges (%)
Bed Width (B)	2	$(B_1) = 76.2$ cm $(B_2) = 91.4$ cm	• Mulch damage (%) • Field efficiency (%)
Spacing (D)	2	$(D_1) = 20$ cm $(D_2) = 15$ cm	• Missing of holes by dibbler (%) • Man-h requirement (man-h ha^{-1})

Table 4. Treatment combinations

S. No.	Treatment Combinations	Description of Treatment-Combinations
1.	$S_1B_1D_1$	Speed 3 kmh^{-1} + Bed Width 76.2 cm + Spacing 20.32 cm
2.	$S_1B_1D_2$	Speed 3 kmh^{-1} + Bed Width 76.2 cm + Spacing 15.24 cm
3.	$S_2B_1D_1$	Speed 5 kmh^{-1} + Bed Width 76.2 cm + Spacing 20.32 cm
4.	$S_2B_1D_2$	Speed 5 kmh^{-1} + Bed Width 76.2 cm + Spacing 15.24 cm
5.	$S_3B_1D_1$	Speed 7 kmh^{-1} + Bed Width 76.2 cm + Spacing 20.32 cm
6.	$S_3B_1D_2$	Speed 7 kmh^{-1} + Bed Width 76.2 cm + Spacing 15.24 cm
7.	$S_1B_2D_1$	Speed 3 kmh^{-1} + Bed Width 90.4 cm + Spacing 20.32 cm
8.	$S_1B_2D_2$	Speed 3 kmh^{-1} + Bed Width 90.4 cm + Spacing 15.24 cm
9.	$S_2B_2D_1$	Speed 5 kmh^{-1} + Bed Width 90.4 cm + Spacing 20.32 cm
10.	$S_2B_2D_2$	Speed 5 kmh^{-1} + Bed Width 90.4 cm + Spacing 15.24 cm
11.	$S_3B_2D_1$	Speed 7 kmh^{-1} + Bed Width 90.4 cm + Spacing 20.32 cm
12.	$S_3B_2D_2$	Speed 7 kmh^{-1} + Bed Width 90.4 cm + Spacing 15.24 cm

Measurement of response parameters

Draft Requirement

The pull was measured using a Monard Digitalizer load cell by placing it along the line of pull between the developed prototype and the tractor (Fig. 10.). The angle between the line of pull and horizontal was measured (9º) and draft was calculated as

$$D = P \cos \theta \quad (1)$$

Where,
D= Draft required, (kp)
P= Pull measured by load cell, (kp)
ɵ= Angle between the line of pull and horizontal

Fig. 9. An overview of operation of tractor operated mulch laying machine

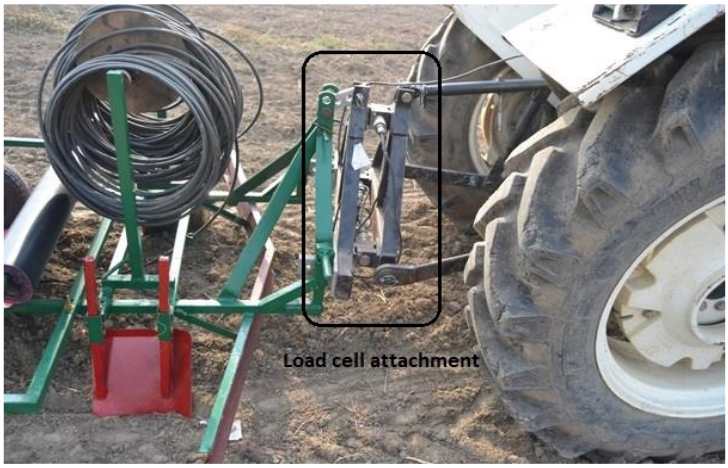


Fig. 10. Measuring draft using Monard Digitalizer load cell

Theoretical field capacity

The theoretical field capacity is the rate of field coverage that was obtained considering if implement was performing its function 100 % of the time at the rated speed and always covering 100 % of its rated width.

$$TFC = \frac{W x S}{10} \quad (2)$$

Where,

TFC = Theoretical field capacity, $ha.h^{-1}$
S = Speed of operation, kmh^{-1}
W = Theoretical width of implement, m

Effective field capacity

The actual field capacity is the actual average rate of coverage by the implement. The total time required covering the mulch in an area was recorded by using stop watch and effective field capacity was calculated as follows:

$$EFC = \frac{A}{T} \quad (3)$$

Where,

EFC = Effective field capacity, $ha.h^{-1}$
A = Actual area covered, ha
T = Effective time, hour

Uncovered mulch edges

The percentage uncovered mulch edge was measured by using a 30 m inch tape on both side of the mulch for 10 m length. The percentage uncovered mulch edges were calculated by using the following formula.

$$\text{Uncovered mulch edges} = \frac{\text{Length of uncovered mulch (both sides),m}}{\text{Total length of mulch laid (both sides),m}} x\ 100 \quad (4)$$

Mulch damage

The percentage of mulch damage was measured by using 30 m inch tape to calculate the damaged area by considering the least possible rectangle portion enclosing damaged area and then percentage of mulch damage was calculated by following formula.

$$\text{Mulch damage (\%)} = \frac{\text{Area of damaged mulch after mulch pass}}{\text{Total area of mulch laid after machine pass}} x\ 100 \quad (5)$$

Field efficiency

The field efficiency is the ratio of effective field capacity to the theoretical field capacity and expressed in per cent.

$$\text{Field efficiency (FE)} = \frac{\text{AFC}}{TFC}\ x\ 100 \quad (6)$$

Where,

AFC = Actual field capacity, $ha.h^{-1}$
TFC = Theoretical field capacity, $ha.h^{-1}$

Missing number of holes by dibbler (%)

The percentage of missing number of holes were calculated by counting the theoretical number of holes made in 10-meter length of machine passed mulch and actual number of holes made in a 10-meter length of machine passed mulch by visual interpretation using following formulas.

$$\text{Percentage of Missing holes} = \frac{\text{Missing number of holes (10m length)}}{\text{Theoretical holes to be made(10m length)}} \text{ x } 100 \quad (7)$$

Man-hour requirement

The man-hour requirement was calculated as per the labour required to perform integrated mulching operation by the machine which involves the tractor operator and a helper required to accompany machine so as to engage and cut the mulch and drip tape at the start and end of bed length.

Statistical Analysis

The factorial design (unbalanced) was used to analyze the data as there were three levels of speed, two levels of bed width and two levels of hole spacing thus factorial design (unbalanced) was used for statistical analysis. SPSS version 21 software was used for analysis of the data.

Numerical Standardization of Responses

The standardization of response parameters was done using design expert software version 10.0.1. While standardization, goal for independent parameters was to keep them in range while among responses, the goal for effective field capacity and field efficiency was to maximize them and for draft requirement, percentage uncovered mulch, percentage mulch damage, percentage missing number of holes and man-hour requirement was to minimize.

RESULTS AND DISCUSSION

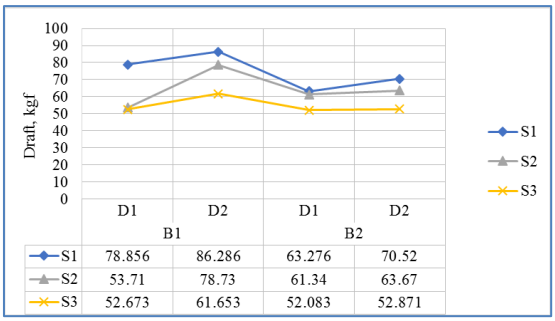
Effect of forward speed, bed width and spacing of holes:

Draft requirement

Draft required to pull the developed machine was affected by all the three independent parameters (Fig. 11). The mean draft required to pull the prototype was found maximum (among selected treatment combinations) as 86.28 kp at bed width of 76.2 cm (B_1), spacing of holes of 15 cm (D_2) and forward speed of 3 kmh^{-1} (S_1).

At forward speed of S_1, S_2 and S_3, the mean draft required to pull the developed prototype was 74.73, 64.36 and 54.82 kp. The draft decreased with the increase in forward speed. It can be attributed to the fact that when developed machine is at rest, there is a static friction between the soil and the working tool of the machine, friction is higher and as soon as tractor gets into motion, the limiting friction comes into play between the working devices of machine and the soil, at that time higher pull is required to overcome limiting friction while as at higher speed, the limiting friction is converted into dynamic friction which decreases the pull to overcome the resistance against it due to the inertia.

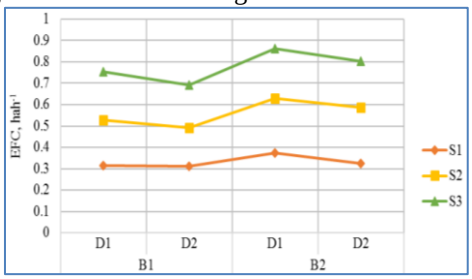
The draft decreased as the bed width increased from 76.2 cm (B_1) to 91.4 cm (B_2) because the laid mulch was held tightly on the wider bed size and the dibbling device operates effectively by punching on the plastic mulch at the required spacing. Draft required was seen increasing as the spacing of holes decreased from 20 cm (D_1) to 15 cm (D_2) due to the clogging of dibbling cones by tearing the mulch when spacing of holes was lesser. Similar trend was reported by [17] that the average draft requirement was 447.8 N (45.6 kp) and reduced as the forward speed was increased during the evaluation of bullock drawn mulching machine at forward speed from 1.33 to 1.36 kmh^{-1}. The results obtained are also in agreement with the findings of other researchers [18].



S1	78.856	86.286	63.276	70.52
S2	53.71	78.73	61.34	63.67
S3	52.673	61.653	52.083	52.871

Fig. 11. Influence of forward speed, bed width and dibbling hole spacing on draft requirement effective field capacity
S: Forward speed of tractor (S_1: 3 kmh^{-1}, S_2: 5 kmh^{-1}, S_3:7 kmh^{-1})
B: Bed Width (B_1:76.2cm, B_2: 91.44 cm) D: Spacing of holes (D_1: 20 cm, D_2 : 15 cm)

Effective field capacity was affected by forward speed and bed width. It increased as the forward speed and bed width increased. The mean effective field capacity was found minimum as 0.312 ha.h^{-1} at forward speed of 3 kmh^{-1} (S_1) and bed width of 76.2 cm (B_1) while as it was found 0.861 ha.h^{-1}, maximum (among the selected treatment combinations) at spacing of holes of 20 cm (D_1), forward speed of 7 kmh^{-1} (S_3) and bed width of 91.4 cm (B_2. The results are in close agreement with the findings of [17,19], where it was reported that the EFC was 0.113 ha.h^{-1} at forward speed of 1.35 kmh^{-1}. The mean effective field capacity also decreased from 0.577 ha.h^{-1} to 0.535 ha.h^{-1} as spacing of holes reduced from 20 cm (D_1) to 15 cm (D_2). This was due to the choking of dibbling cones by shredding the mulch when spacing of holes was lesser (15 cm) but at higher spacing of holes, the punching of mulch was executed without ripping due to the inertia of the dibbling wheel. Consequently, spacing of holes was found significant at the 5% level of significance.



S: Forward speed of tractor (S_1: 3 kmh^{-1}, S_2: 5 kmh^{-1}, S_3 :7 kmh^{-1})
B: Bed Width (B_1:76.2cm, B_2: 91.44 cm)
D: Spacing of holes (D_1: 20 cm, D_2 : 15 cm)
Fig. 12. Variation due to forward speed, bed width and dibbling hole spacing on effective field capacity

Field efficiency

Field efficiency was affected by all the three independent parameters. It increased with increase in forward speed and bed width while it decreased with the decrease in spacing of holes (Table 5).

Field efficiency was found maximum as 73.97% at forward speed of 7 kmh^{-1} (S_3) and bed width of 91.4 cm (B_2). FE was found minimum as 57.69 % at forward speed of 3 kmh^{-1} (S_1) and bed width of 76.2 cm (B_1). In general, field efficiency increased as forward speed and bed width increased from 3 kmh^{-1} (S_1) to 7 kmh^{-1} (S_3) and 76.2 cm (B_1) to 91.4 cm (B_2), respectively. Other researchers also reported that field efficiency increased with forward speed and observed maximum field efficiency of 69.67 % at the forward speed of 1.35 kmh^{-1} [17]. The field efficiency was observed lower at forward speed of 7 kmh^{-1} because at this speed dibbling wheel wrap the mulch on dibbling cones.

Field efficiency increased from 66.32 to 69.43 % as the spacing of holes increased from 15 cm (D_2) to 20 cm (D_1). This is attributed to the rationale that as the distance between the dibbling cones is lesser, larger surface area of plastic mulch film is attained under the dibbling cones and hence punching effect of dibbling cones is reduced, instead plastic mulch film elongates over the dibbling cones and the mulch film is teared off, tractor has to be stopped and choked dibbling cones need to be cleaned to prevent further mulch damage.

While as when distance between dibbling cones is larger, very less surface area of plastic mulch comes under the dibbling cone. Moreover, due to the inertia of wheel, dibbling cones punch through the mulch film without choking the dibbling device.

Mulch damage

The mulch damage was found increasing as forward speed of tractor increased from S_1 to S_3 (Table 6). Mean mulch damage was found minimum as 2.86 % at forward speed of 3 kmh^{-1} and spacing of holes of 20 cm (D_1) while it was found maximum as 14.76 % at forward speed of 7 kmh^{-1} and bed width of 91.4 cm (B_2). The increased mulch damage at higher speeds was due to the jumping of dibbling wheel which results in tearing of mulch due to the sharp dibbling cone. Mulch damage decreased as the bed width increased from B_1 (76.2 cm) to B_2 (91.4 cm) due to the choking of the dibbling cones as when bed width is lesser, the mulch is kept loose on the bed. The mulch damage was seen decreasing as the spacing of holes reduced from 20 (D_1) to 15 cm (D_2).

Table 5. Variation in field efficiency (%) due to forward speed, bed width and spacing of holes

B.W / S.H / Speed	Mean ± S. D						
	B_1			B_2			
	D1	D2	Sub-Mean (SB)	D1	D2	Sub-Mean (SB)	Total Mean
S_1	62.70 ± 3.53	57.69 ± 4.75	60.19 ± 4.64	72.74 ± 1.48	69.22 ± 2.27	70.98 ± 2.57	65.59 ± 6.67
S_2	66.86 ± 0.76	64.81 ± 1.38	65.84 ± 1.50	73.49 ± 0.97	70.51 ± 0.72	72.00 ± 1.80	68.92 ± 3.58
S_3	66.83 ± 0.51	64.20 ± 1.97	65.51 ± 1.93	73.97 ± 2.13	71.47 ± 0.93	72.72 ± 2.01	69.12 ± 4.20
Sub-Mean (BD)	65.46 ± 2.76	62.23 ± 4.33	63.85 ± 3.89	73.40 ± 1.48	70.40 ± 1.61	71.90 ± 2.15	67.87 ± 5.12
Total Mean	63.84 ± 3.54			71.9 ± 1.54			
C.D ($P \leq 0.05$)							
D : 0.215							
S x B : 1.859							

Note: Only the factor(s) or interaction(s) with C.D value mentioned (above) are significant otherwise non-significant.

S = Forward speed of tractor : S_1= 3 kmh^{-1}, S_2 = 5 $km.h^{-1}$, S_3 = 7 kmh^{-1}

B = Bed Width : B_1 = 76.2 cm & B_2 = 91.44 cm

D = Spacing of Holes : D_1 = 20 cm & D_2 = 15 cm

Table 6. Alteration in mulch damage (%) due to forward speed, bed width and spacing of holes

B.W / S.H Speed	Mean ± S. D B_1 D1	B_1 D2	B_1 Sub-Mean (SB)	B_2 D1	B_2 D2	B_2 Sub-Mean (SB)	Total Mean
S_1	2.86 ± 0.70	2.86 ± 1.07	2.86 ± 0.81	3.40 ± 1.47	2.93 ± 0.83	3.16 ± 1.04	3.01 ± 0.90
S_2	4.23 ± 2.55	4.03 ± 1.43	4.13 ± 1.85	3.83 ± 1.97	4.40 ± 0.70	4.11 ± 1.36	4.12 ± 1.55
S_3	9.70 ± 1.51	14.76 ± 2.95	12.23 ± 3.43	4.16 ± 2.31	5.93 ± 0.80	5.05 ± 1.82	8.64 ± 4.59
Sub-Mean (BD)	5.60 ± 3.48	7.22 ± 5.93		3.80 ± 1.70	4.42 ± 1.46		
Total Mean	6.41 ± 4.70			4.11 ± 1.57			

C.D ($P \leq 0.05$)

S x B : 1.381

S x D : 1.381

Note: Only the factor(s) or interaction(s) with C.D value mentioned (above) are significant otherwise non-significant.

S = Forward speed of tractor : S_1= 3 kmh^{-1}, S_2 = 5 $km.h^{-1}$, S_3 = 7 kmh^{-1}

B = Bed Width : B_1 = 76.2 cm & B_2 = 91.44 cm

D = Spacing of Holes : D_1 = 20 cm & D_2 = 15 cm

Man-hour requirement

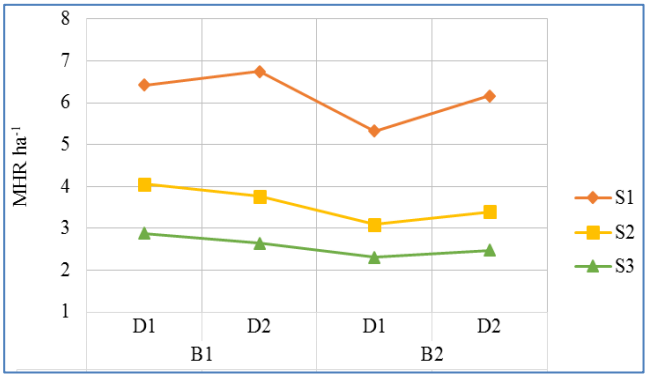
Man-hour requirement was found affected by the forward speed and bed width. It decreased as the forward speed and bed width increased. Man-hour requirement was minimum (among selected treatment combinations) as 2.31 man-hours ha^{-1} at speed of 7 kmh^{-1} (S_3), spacing of holes of 20 cm (D_1) and bed width of 91.4 cm (B_2). while it was maximum (among selected treatment combinations) as 6.75 man-hours per hectare (ha^{-1}) at forward speed of 3 kmh^{-1} (S_1) and bed width of 76.2 cm (B_1). Man hour requirement depends on time required to cover the field since the field coverage depends on forward speed of tractor and width of operation therefore, increase in forward speed and bed width from 3 kmh^{-1} (S_1) to 7 kmh^{-1} (S_3) and from 76.2 cm (B_1) to 91.4 cm (B_2) respectively decreased the man-hour required to cover one hectare by mulching. The results are in close agreement with the findings of other researcher [19,20].

Missing number of holes

The missing number of holes increased in general as forward speed of tractor and bed width increased (Fig. 14). It was found maximum as 10.96 % at speed of 7 kmh^{-1}, bed width of 76.2 cm (B_1) and at spacing of holes of 15 cm (D_2) while it was minimum at speed of 3 kmh^{-1} (S_1), bed width of 91.4 cm (B_2) and spacing of holes of 20 cm (D_1).

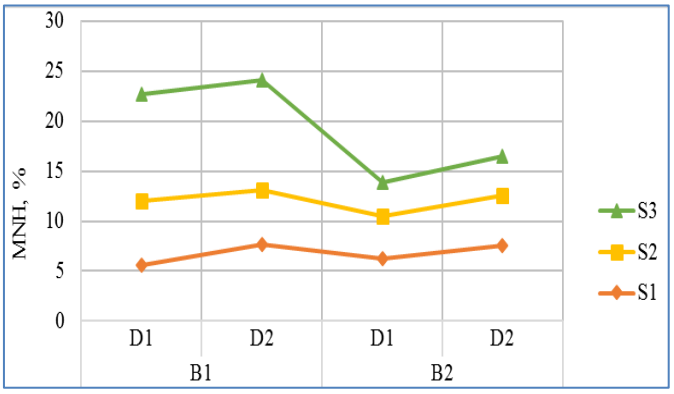
The missing number of holes dependent on bed width and forward speed of tractor as the forward speed affects the inertia that causes the punching of mulch film and bed width determines the loosen or tighten mulch film on the prepared bed.

As soon as forward speed increases, missing holes increases due to jumping of dibbling wheels which causes damage as well as missing number of holes on the mulch film while as increasing bed width results in tightening of mulch film on the top bed width on which punching by dibbling cone is effective instead of wrapping of mulch film along the direction travel (in case of loosen mulch film on the top bed width).



S = Forward speed of tractor (S_1: 3 kmh^{-1}, S_2: 5 kmh^{-1}, S_3 :7 kmh^{-1})
B = Bed Width (B_1:76.2cm, B_2: 91.44 cm)
D = Spacing of holes (D_1: 20 cm, D_2 : 15 cm)

Fig. 13. Variation due to forward Speed, bed width and hole spacing on man-h requirement (MHR)



S = Forward speed of tractor (S_1: 3 kmh^{-1}, S_2: 5 kmh^{-1}, S_3 :7 kmh^{-1})
B = Bed Width (B_1:76.2cm, B_2: 91.44 cm)
D = Spacing of holes (D_1: 20 cm, D_2 : 15 cm)

Fig. 14. Variation due to forward Speed, bed width and hole spacing on dibbling hole missing (MNH)

Uncovered mulch

The uncovered mulch edge (%) was found affected by forward speed of tractor. It increased as forward speed increased from 3 kmh^{-1} (S_1) to 7 kmh^{-1} (S_3).

It was found minimum (among the selected treatment combinations) as 3.60 % at the forward speed of 3 kmh^{-1} while it was found maximum (among selected treatment combinations) as 10.23 % at forward speed of 7 kmh^{-1} (Table 7). With increase in speed left some patches of mulch edges uncovered since some of the soil clods disturb the soil movement along the direction projected by covering device, Hence, statistical analysis revealed that the percentage uncovered mulch damage was affected by the forward speed of tractor and was found significant at 5 % level of significance.

Table 7. Influence of forward speed, bed width and spacing of holes on uncovered mulch (%)

B.W / S.H Speed	Mean ± S. D						
	B_1			B_2			
	D1	D2	Sub-Mean (SB)	D1	D2	Sub-Mean (SB)	Total Mean
S_1	2.50 ± 0.26	4.63 ± 1.93	3.56 ± 1.70	3.03 ± 0.11	4.23 ± 1.95	3.63 ± 1.40	3.60 ± 1.48
S_2	4.73 ± 2.35	3.53 ± 1.36	4.13 ± 1.84	4.50 ± 2.25	6.13 ± 2.77	5.13 ± 2.43	4.72 ± 2.14
S_3	12.66 ± 6.58	11.50 ± 3.11	12.08 ± 4.65	6.16 ± 1.90	10.60 ± 4.71	8.38 ± 4.02	10.23 ± 4.57
Sub-Mean (BD)	6.63 ± 5.80	6.55 ± 4.22		4.56 ± 2.00	6.98 ± 4.05		
Total Mean	6.59 ± 5.01			5.77 ± 3.02			
C.D ($P \leq 0.05$)	S : 1.757						

Note: Only the factor(s) or interaction(s) with C.D value mentioned (above) are significant otherwise non-significant.

S = Forward speed of tractor : S_1= 3 kmh^{-1}, S_2 = 5 $km.h^{-1}$, S_3 = 7 kmh^{-1}
B = Bed Width : B_1 = 76.2 cm & B_2 = 91.44 cm
D = Spacing of Holes : D_1 = 20 cm & D_2 = 15 cm

Standardization of the Responses

The optimum response values were obtained from optimization software "Design Expert 10.0.1". The machine operating parameters were standardized so that all the responses maximize the overall performance of developed prototype. Therefore, the standardized response parameters were obtained as 52.65 kp ; 0.80 $ha.h^{-1}$; 71.50 %, and 2.59 man-hour ha^{-1} for draft requirement, effective field capacity, field efficiency, and man-hour requirement, respectively.

Similarly, other standardized response parameters were obtained as 6.942, 3.592 and 3.711 % for percentage uncovered mulch, percentage mulch damage and percentage missing number of holes respectively.

The operating parameters were standardized as forward speed of 3 kmh^{-1}, bed width of 91.4 (B_2) and spacing of holes of 20 cm (D_1).

CONCLUSIONS

A tractor drawn plastic mulch laying machine was developed to mechanize the conventional plastic mulching, laying drip irrigation pipes (surface) and dibbling hole in the mulch for seedling transplanting which, worked to facilitate the implementation of this method, saves time, labour and increases timeliness of operation. The draft requirement decreased with the increase in forward speed (3.0 to 7.0 kmh^{-1}), bed width (76.2 to 91.4 cm) and dibbling hole spacing (15.2 to 20.3 cm). Although at low speed (3.0 kmh^{-1}), the actual field capacity and field efficiency decreased about 57% and 5.0%, respectively while draft required increased about 36 %, compared to the speed of 7.0 kmh^{-1}.

However, at a speed of 3.0 kmh^{-1}, the mulch damage, un-covered mulch percentage and missing of dibbling hole decreased about 65%, 64% and 7.0 %, respectively. The study recommends using the developed machine to install a raised-bed and laying both of plastic mulch and drip irrigation pipes on bed surface at a speed of 3 $km.h^{-1}$.

In the future, this technology could be modified and implemented to mechanize plastic mulch laying operation, where human fatigue and drudgery are involved.

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INTEGRISANA MAŠINA ZA POLAGANJE PLASTIČNOG MALČA – ODRŽIVA TEHNOLOGIJA ZA ODRŽIVU POLJOPRIVREDNU PROIZVODNJU

Shoaib Amin[1], Jagvir Dixit[1*] and M. Muzamil[1]

[1]Division of Farm Machinery and Power Engineering, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, India

Abstract: Razvijena konstrukcija vučene traktorske mašine za polaganje malča kako bi se integrisale operacije i popravili nedostatci u pogledu rada povezanim sa konvencionalnim operacijama polaganja malča.

Prototip mašine integriše operacije u jednom prolazu: formiranje posteljice, polaganje trake za navodnjavanje, prostiranje malča, pokrivanje malča i bušenje odgovarajućih rupa-otvora za rasad na pokrivaču i malču.
Razvijeni prototip nošene mašine testiran je sa tri različite brzine napred (3,0; 5,0; 7,0 kmh^{-1}), dva nivoa širine posteljice (76,2 i 91,4 cm) i dva nivoa razmaka rupa za rasad (15,2 i 20,3 cm).

Rezultati predviđenog eksperimenta i ispitivanja za ovu mašinu pokazuju da se sila vuče menja sa povećanjem brzine traktora napred (3,0 do 7,0 kmh^{-1}), promenom širine osnove ležišta (76,2 do 91,4 cm) i promenom razmaka rupa za rasad (15,2 do 20,3 cm).
Učinak mašine (agregata) povećava sa povećanjem brzine i to napred, širine osnove i razmaka rupa za rasad. Iako se pri maloj brzini (3,0 kmh^{-1}), stvarni učinak i efikasnost u polju smanjuju za približno 57% odnosno 5,0%, dok se sila vuče povećava za približno 36%, sa povećanjem brzine do 7,0 kmh^{-1}. Međutim, pri maloj brzini od 3,0 kmh^{-1}, oštećenje pokrivača-malča je smanjeno za 65 %, nepokrivenost malča smanjena za 64% i nedostatak rupa za rasad iznosi do 7%.

Standardna vrednost za silu vuče zahteva 63,27 kp, efektivni učinak na polju je 0,40 hah^{-1} i ukupni učinak je 72,7%. Nepokriveni malč 3,1 %, oštećenja malča 3,4 % i nedostajući broj rupa za rasad je 6,25% .
Potreba za radnim satima i troškovi rada malčiranja sa ovom novom mašinom smanjeni su približno 97% i 75% u poređenju sa konvencionalnom metodom polaganja malča.
U ovoj studiji preporučuje se korišćenje nove integrisane mašine za formiranje uzdignute gredice (bankovi), polaganje plastičnih cevi za navodnjavanje i izradu rupa za rasad brzinom od 3 kmh^{-1} da bi se postigla bolja efikasnost.

Ključne reči: *Mašina za polaganje malča, zahtev za vuču, učinak, oštećenje malča, širina osnove trake, razmak rupa, nepokriveni malč*

Prijavljen:
Submitted: **30.09.2021.**
Ispravljen:
Revised: **20.12.2021.**
Prihvaćen:
Accepted: **15.02.2022.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLVII
Broj 1, 2022.
Strane: 79 – 88

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLVII
No. 1, 2022.
pp: 79 – 88

UDK: 631.3:664.2.036

Original scientific paper
Originalni naučni rad
doi: 10.5937/PoljTeh2201090I

ECONOMIC VIABILITY ASSESSMENT OF BAMBARA NUT MILLING-SIEVING MACHINE

Ijeoma Francisca Ikechukwu*, Bethrand Nduka Nwankwojike, Ibiam Fidelis Abam

Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

Abstract: A novel continuous process milling-sieving machine specially developed recently for processing Bambara nut to flour was assessed for economic viability in this study with multi-criteria cost-benefit analysis measures in order to advance its acceptance and commercialization. This involved determination and assessment of its payback period, accounting rate of return, net present value and benefit cost ratio using the prevailing economic indicators/market prices of materials in Abia State of Nigeria between January and December, 2020. The decision measures applied include that the payback period of this machine must be less than its expected useful life of ten years and its benefit cost ratio must be greater than one. In addition, the investment's rate of return must be greater than the upper limits of Nigerian banks' lending and fixed deposit interest rates in order to justify its possible funding from personal savings and bank credits**.** Results showed that this innovation is economically viable due to its payback period of 1.5years and benefit cost ratio of 1.69 are as desired. Also the 46.89% accounting rate of return of this machinery outweighed Nigerian banks maximum fixed deposits return of 17% and prime lending rate of 29%. Thus, adoption of this novel milling-sieving machine is recommended for Bambara flour production because of its positive economic potential.

Keywords: *Bambara nut, flour production, investment analysis, machine, milling, sieving*

*Corresponding Author. E-mail: ikechukwuijoma7@gmail.com

INTRODUCTION

Bambara groundnut (*Vigna subterranea*) constitutes one of the crops with high potential for attainment of food security and poverty alleviation in Africa because it is climate/drought-resilient crop which bears outstanding medicinal/nutritional quality nuts [1]. The works of [2] and [3] revealed Bambara nut as a complete food diet due to its superlative proteins with over plus lysine, carbohydrates, fats, oil, iron, ash, potassium, sodium, calcium, fiber and probiotic bacteria contents. Therapeutic potentials of this nut are obvious from [1,4,5,6] which reported its application in control of malnutrition/kwashiorkor, diarrhea, irritable bowel syndrome, prolonged menstruation and other health problems. Thus, the high demand of Bambara nut especially its flour in both local and international market. Bambara nut can be consumed as freshly cooked nuts but processing of the dry nut into flour lends it to unlimited food diets/beverages such as fufu, relish, soup, moin moin (okpa), biscuit, bread pastries and food thickeners [6, 7]. Processing of Bambara flour involve grinding of its nuts to micro grains and sieving of the milled grains to separate its food and fibrous contents. Hence, the decades of searching for full mechanized Bambara flour processing system before the advent of a continuous process milling-sieving machine (fig. 1) specially developed by [8] for Bambara nut milling-sieving recently. The years of this strenuous searching cannot be over emphasized due to drudgery and unhygienic nature of the mechanized multiple milling and manual sieving operations which presently prevails in this sector. Unsuccessful adoption of other grain flour processing machineries for milling and sieving operations in Bambara flour production as well as development of specific machine for them over the years was attributed by [8] to high binding force between the nut's coat and cotyledon due its phenolic compound content and the coat does not possess inherent crack making it impermeable to water, heat and chemical. The novel machine fosters continuous milling and sieving operation during processing of dry Bambara grains into flour and performs with throughput and extraction efficiency of 117.76 kg/h and 98.45% respectively. This Bambara nut milling and sieving machine improved the processing capacity, the flour quality and the extraction efficiency to less than 2% food loss. It also promotes hygiene in this sector because it eliminated human contact with the milled grain during its operation. Since every investor's interest is sustainable positive financial return of technology, investment analysis of this machinery is vital for its wide adoption and investment.

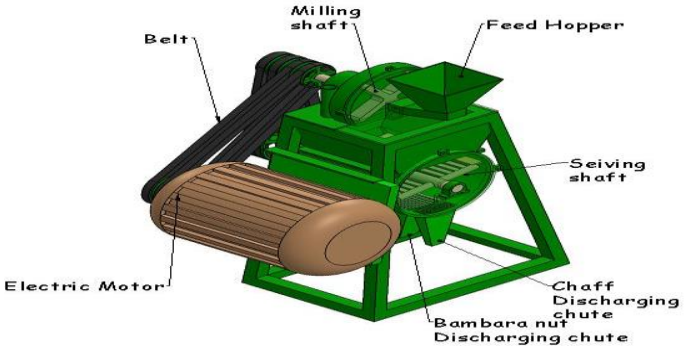

Fig. 1. The Bambara nut milling-sieving machine

Investment analysis is a broad term with different methods of evaluating economic developments of projecting past or expected returns to predict future performance of systems [10,11]. It determines risks, yield potential or price movements of any system studied with suitable entry price, the expected time horizon for holding an investment and the role the investment will play in the portfolio of whole as key factors [11]. Thus, [12] and [13] showed machinery investment analysis as a key determinant of business profitability. Machinery investment analysis involves computation of return on investment of individual or group of machines/plant using the contract rates of all work the machine does or will do in order to ascertain their level of capitalization [12]. Although, investment decision pointers such as benefit cost ratio, net present value, payback period and accounting rates of returns are used individually to ascertain the economic efficiency of systems, their integrated methodology called benefit-cost analysis are often used in new machinery assessment because of its high prediction accuracy [9, 14]. Cost-benefit analysis is a tool for evaluating all potential costs and revenues that may be generated prior to actual implementation of investment decisions in order to avoid the risk of going into an unprofitable venture and wasting valuable time and money [15]. This involves identification, categorization, projection, monetization, computing and comparison of present values of costs and benefits over the lifespan of an investment [14]. Integrated approach of benefit-cost analysis indicates that an investment is worthy when its projected potential benefits outweigh its costs; its rate of return exceeds the required minimum rate; its payback period is less than its salvage period and its net present value exceeds zero [9]. Application of machinery investment analysis in grain processing sector is not new because [12] showed its overwhelming decades of merit in grain growing enterprises. [16] revealed cost-effectiveness of a gari processing machines in Ondo State in Nigeria while [17]established possibility of small-scale palm oil processing in River State in Nigeria with this method. [18] showed a cost benefit ratio of more than one when cost and returns of cassava production in Ekiti state were evaluated. [19] also indicated that the overview of the novel palm nut-pulp machine is profitable when compared to the traditional technique of processing through cost benefit analysis.

Employed benefit [20] cost analysis to substantiate mechanized maize crop farming to be more lucrative than the traditional system in Pakistan.

Since every wise investors/managers will never embrace a new technology without the conviction of its profitability and wide reception which is also applicable to the novel continuous process milling-sieving machine for Bambara flour processing, paramount for drudgery and waste reduction in this sector. This study therefore applied cost-benefit methodologies to determine its investment prospects of the recently developed continuous process milling-sieving machine for Bambara flour production to ascertain its economic potential.

METHODOLOGY

The integrated Bambara nut milling-sieving machine was assessed for economic viability in this study with multi-criteria cost-benefit analysis measures. This involved determination and assessment of its payback period, accounting rate of return, net present value and benefit cost ratio using the prevailing economic indicators/market prices of materials in Abia State of Nigeria between January and December, 2020.

The decision measures applied include that the payback period of this machine must be less than its expected useful life of ten years, its net present value and benefit cost ratio must be greater than zero and one respectively. In addition, the investment's rate of return must be greater than the upper limits of Nigerian banks' lending and fixed deposit interest rates in order to justify its possible funding from personal savings and bank credits [21].

Records revealed the standard business registration cost, interest rate, corporate income tax rate for Nigeria companies (with more than one million naira turnover) as ₦25,000, 14% and 30% respectively within this study period. [22,23]. The fixed deposit interest rate of Nigerian banks as at December 31, 2020 fall between 7.09 to 16% while their prime lending rates for agriculture or manufacturing ranges from 7 to 29% [22] The maximum annual rent of required space for this business is ₦150,000 while ₦30,000 constitute Nigeria minimum wage per month during this investigation. Five (5) working days per week of 8 hours per day with one-hour break was also applied. The average unit cost of Bambara, and diesel during this period were ₦254.1/kg, and ₦190/litre respectively while the Bambara flour and chaff from Bambara sale for ₦367/kg and ₦65/kg respectively. The payback period (P_b), accounting rate of return (*ARR*), net present value (NPV) and benefit cost ratio (*BCR*) of the Bambara flour milling-sieving machine were computed from its financial data collected and optimal performance parameters determined in this study using the following relations in equation (1) to (6) given by [14,24]

$$P_b = \frac{C_i}{B_n} \tag{1}$$

$$ARR = \frac{B_n}{C_i} \tag{2}$$

$$NPV = \sum_{t=1}^{n} \frac{B_{nt}}{(1+r_i)^t} - C_i \tag{3}$$

$$BCR = \frac{PVB}{PVC} \tag{4}$$

$$PVC = \sum_{0}^{t} \frac{C_i}{(1+r_i)^t} \tag{5}$$

$$PVB = \sum_{0}^{t} \frac{B_n}{(1+r_i)^t} \tag{6}$$

Where;C_i, B_n and B_{nt} constitute the initial investment cost, average annual net benefit (cash inflow) and net cash inflow at time, *t* respectively while PVC and PVB, are the respective present values of costs and benefits of the machine.

RESULT AND DISCUSION

The unit cost of fabrication of the integrated Bambara flour processing machine was calculated as two hundred and nineteen thousand two hundred naira (₦219, 200) only as shown in (Tab. 1).

The salvage value of the integrated Bambara flour processing machine at the end of its useful life was zero as shown in (Tab. 2) with a replacement value of six hundred and thirty five thousand nine hundred and ninety thousand ninety five kobo (₦635, 990. 095) only. Annual raw material cost of this machine, C_r was computed as ₦61, 821, 9201, annual sales, S_a was estimated as N105, 243,242.8. The Machine's Replacement Value, MRV was evaluated as ₦635, 99009; the annual maintenance cost (AMC) for this machine was taken as 2.5% of AMC, ₦249, 641.6. The net cash flow for each period is shown in (Tab. 3) while recurring and nonrecurring costs and revenues are presented in (Tab. 4). Table 4 shows that ₦61,821,920.16 and ₦ 249,641.6 are required annually for Bambara seed and energy respectively, ₦ 15,899.75 is required annually to maintain this machine, thus, an annual initial sum of ₦ 94,593,741.00 is required for investment in this technology. Average cash inflow and profit of ₦ 65,471,209 and ₦ 65,455,309.25 respectively can be obtained yearly. The negative cash flow for the first year is due to the purchases of fixed assets, however, positive cash inflow was realized afterwards. The Payback period, Accounting Rate of Return, Net Present Value and Benefit Cost Ratio were estimated as 1.5, 46.89%, ₦421, 075,135.6 and 1.69 respectively. This means that with an expected rate of return of 46.89% at a payback period of 1.5, an average of a year and six months is required to recuperate investment in this technology. Benefit Cost Ratio of 1.69 implies that for every ₦ 1 invested in this technology, ₦ 1.69 will be realized. A positive Net Present Value further justifies the viability of investment in this technology for Bambara flour processing. The investment potentials of Bambara nut milling-sieving machine for Bambara flour production also revealed annual cash inflow of ₦ 42,942,136, with Net Present Value, Benefit Cost ratio, Accounting rate of returns and payback period of ₦276,236,879.00, 1.69, 46.89% and 1.5 respectively as shown in (Tab.4 to Tab.5)). An annual initial sum of ₦ 62,522,662.00 is required for investment in this technology while ₦ 15,899.75 constitute the annual maintenance cost. Positive net present value (> 0) is desirable of any worthy investment while 46.89% annual return of this machine is encouraging because it outweighed banks maximum fixed deposits return of 16% and prime lending rate of 29% in Nigeria. This investment is thus recommended in order to increase Bambara flour supply as well as boost the profit margin of Bambara flour production.

Table 1: Initial cost of the Bambara nut milling-sieving machine

S/No	Description	Unit	Quantity	Unit Price ₦ K	Amount ₦ K
1	30 x 2743 mild steel rod	Mm	1	3200.00	32000.00
2	Mild steel rod (20 x 2000)	Mm	1	2400.00	2400.00
3	Mild steel pipe (2438 x 1219 x 3)	Mm	1	3500.00	3500.00
4	Mild steel plate (2438 x 1219 x 5)	Mm	1	8000.00	12,000.00
5	Mild steel plate (2438 x 1219 x 3)	Mm	2	12000.00	12000.00
6	Mild steel bar (75mm equal section)	Length	2	17000.00	14000.00
7	Angular contact bearing	6306SK	4	1420.00	5680.00
8	V – belt (A1295 – IS; 2494)	Nos	1	5000.00	5000.00
9	V – belt (A 965 – IS; 2494)	Nos	1	2500.00	2500.00
10	Cast iron pulley (ϕ200)	Mm	2	5500.00	11000.00
11	Cast iron pulley (ϕ150)	Mm	1	4500.00	4500.00
12	Cast iron pulley (ϕ100)	Mm	1	4500.00	4500.00
13	M10 x 1.25 bolts and nuts	Mm	10	50.00	1500.00
14	M12 x 1.5 bolts and nuts	Mm	30	50.00	1500.00
15	Paint	Liters	3	1300.00	3900.00
16	Electrode	Pkt	2	1400.00	2800.00
17	5.5Hp Electric motor	Hp	1		50,000.0
18	50kg of bambara seed	Kilo	50		38,000.0
19	Stainless steel sieve	Mm	1		15000.0
20	Stainless steel pipe	Mm	1		3500.00
	SUB-TOTAL				**₦219 200.00**

Table 2. Salvage value of the Bambara nut milling-sieving machine

Year	Opening balance	Depreciation (at 20%)	Salvage value at the end of year
1	219,200	43840	175,360
2	175,360	35072	140,288
3	140,288	28057.6	112,230
4	112,230	22446.08	89,784
5	89,784	17956.8	71,827
6	71,827	14365.44	36,462
7	57,462	11492.4	29,970
8	45,970	9193.92	20,776
9	36,776	7355.216	10,421
10	29,421	5884.16	0

Table 3. Analysis of net cash flow of the Bambara nut milling-sieving machine

End of year	Net Cash Flow before tax
0	-219,200
1	42,939,782
2	42,939,782
3	42,939,782
4	42,939,782
5	42,939,782
6	42,939,782
7	42,939,782
8	42,939,782
9	42,939,782
10	42,963,319
Total annual cash flow	429,421,357
Average Annual Cash flow	42,942,136

Table 4. Analysis of annual costs/revenues of the Bambara nut milling-sieving machine

NON RECURRING COSTS AND REVENUES	**Costs (₦)**	**Revenue (₦)**
Initial cost	219,200	
Sales of equipment after useful period		23,537
Total	219,200	**23,537**
RECURRING ANNUAL COSTS AND REVENUES	Costs (₦)	**Revenue (₦)**
OPERATIONAL AND MAINTENANCE (O&M) COST		
Direct Costs		
Labour (minimum wage = N18,000 monthly)	216,000	
Material cost		
Bambara nut	61,821,920.16	
Indirect costs		
Maintenance	15,899.75	
Power	249,641.6	
other cost		
REVENUE		
Sales of flour		89,375,374
Sales of chaff		15,867,870
Total	62,303,462	105,243,244
Total Annual Initial Investment	62,522,662	
Profit		
Payback period	1.5	65,455,309.25

Table 5. Evaluation benefit cost ration of the Bambara nut milling-sieving machine

Year	Investment Cost (₦)	Operating cost (₦)	Total cost (₦)	Sales (₦)	Salvage Value (₦)	Total Benefit (₦)	Present Value Cost (₦)	Present Value Benefit (₦)
0	219,200	62,303,462	62,522,662	105,243,244	0	105,243,244	62522662	105243244
1		62,303,462	62,303,462	105,243,244	175,360	105,418,604	55135807.08	93290800
2		62,303,462	62,303,462	105,243,244	140,288	105,383,532	48792749.63	82530763.57
3		62,303,462	62,303,462	105,243,244	112,230	105,355,474	43179424.45	73016628.35
4		62,303,462	62,303,462	105,243,244	89,784	105,333,028	38211880.04	64602718.72
5		62,303,462	62,303,462	105,243,244	71,827	105,315,071	33815823.05	57160801.2
6		62,303,462	62,303,462	105,243,244	57,462	105,300,706	29925507.12	50577880.04
7		62,303,462	62,303,462	105,243,244	45,970	105,289,214	26482749.67	44754301.08
8		62,303,462	62,303,462	105,243,244	36,776	105,280,020	23436061.65	39602117.77
9		62,303,462	62,303,462	105,243,244	29,421	105,272,665	20739877.57	35043673.55
10		62,303,462	62,303,462	105,243,244	0	105,266,781	1835387395	31010367.13
Total							400,596,416	676,833,295
NPV		₦276,236,879						
BCR		1.69						

CONCLUSION

This study showed that this machinery is worthy of investment since its payback period is less than its salvage period and its benefit-cost ratio and net present value are more than one and zero respectively. In addition, the investment analysis of this machine showed that it is viable economically because of its positive capital recovery potentials. The machine's payback period of 1.5years is far less than its useful life of 10years, while its 46.89% accounting rate of return outweighed Nigerian banks maximum fixed deposits return of 17% and prime lending rate of 29%. Therefore, adoption of this novel milling-sieving machine is recommended for Bambara flour production because of its positive economic prospects

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PROCENA EKONOMSKE ODRŽIVOSTI MAŠINE ZA MLEVENJE I PROSEJAVANJE BAMBARA ORAHA

Ijeoma Francisca Ikechukwu, Bethrand Nduka Nwankwojike, Ibiam Fidelis Abam

Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

Apstrakt: Nova mašina za mlevenje i prosejavanje koja je nedavno specijalno razvijena za preradu Bambara oraha (*Vigna Subterranea (L.) Verdc.*) u brašno. Mašina je procenjena na ekonomsku održivost u ovoj studiji sa merama analize troškova sa više kriterijuma kako bi se unapredilo njeno prihvatanje i komercijalna uptreba. Ovo je uključivalo utvrđivanje i procenu perioda otplate, računovodstvene stope prinosa, neto sadašnje vrednosti i odnosa troškova koristeći preovlađujuće ekonomske pokazatelje/tržišne cene materijala u državi Abija u Nigeriji, za period između januara i decembra 2020. godine.

Mere i odluke koje se primenjuju uključuju da period isplativosti ove mašine mora biti kraći od očekivanog korisnog veka trajanja od 10 godina, a odnos faktora koristi i troškova mora biti veći od jedan. Pored navedenog, stopa isplativosti investicije mora biti veća od gornje granice banaka u Nigeriji na pozajmice i fiksne kamatne stope na depozite kako bi opravdalo moguće finansiranje iz lične štednje i bankarskih kredita.

Rezultati istraživanja su pokazali da je ova inovacija ekonomski isplativa zbog perioda otplate od 1,5 godina, kod odnos troškova i dobiti koji iznosi 1,69.

Takođe, računovodstvena stopa prinosa konstrukcije ove mašine od 46,89% nadmašila je maksimalnu isplativost fiksnih depozita kod banaka u Nigeriji od 17% i primarne kreditne stope od 29%.

Primena ove nove mašine za mlevenje i prosejavanje Bambara oraha u brašno preporučuje se zbog njenog pozitivnog ekonomskog potencijala.

Ključne reči: *Bambara orah, proizvodnja brašna, investiciona analiza, mašina, mlevenje, prosejavanje*

Prijavljen: *Submitted*:	**22.10.2021.**
Ispravljen: *Revised*:	**05.01.2022.**
Prihvaćen: *Accepted*:	**05.02.2022.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLVII
Broj 1, 2022.
Strane: 89 – 93

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLVII
No. 1, 2022.
pp: 89 – 93

UDK:338.43.1.

Pregledni rad
Review paper
doi: 10.5937/PoljTeh2201100J

THE IMPORTANCE OF ELECTRONIC STORAGE OF DOCUMENTATION IN AGRICULTURAL ENTERPRISES IN THE REPUBLIC OF SERBIA

Dejan Jeremić*[1], Slobodan Stanojević[2]

[1]College of Management and Economics, Karadjordjeva 52, 34000, Kragujevac, Republic of Serbia
[2]Faculty of Applied Management, Economics and Financ, Jevrejska 24-1, 11000 Belgrade, Republic of Serbia

Summary: In this study, the authors point out the importance of archiving documentation in agricultural enterprises in the Republic of Serbia. The aim of the study was to point out the importance of a new approach (application of electronic archiving) in agricultural enterprises. This is of great importance because documentation is the basis for financial reporting and financially stable management in the company. The survey was conducted in 144 agricultural enterprises and we found that financial management and control was introduced in 79 enterprises, and that an insufficient level of control at the enterprise level was present in 65 enterprises. By presenting the Phi/Cramer correlation coefficient, the authors proved the existence of statistical significance (p = .00) and achieving more secure archiving of documentation in agricultural enterprises that have introduced a system of financial management and control in their regular operations.

Keywords: *documentation, financial management and control.*

*Corresponding Author. E-mail address: office@sequesteremployment.com

INTRODUCTION

Corporate management in the economy, and especially management in agricultural enterprises, requires adequate storage and archiving of documentation [1-5] in enterprises. Archiving documentation in companies is one of the most important tasks that must be done in order to reduce the general risk of doing business in companies [6-10].

Numerous studies emphasize the importance of applying standards in business. One of the ways to perform general standardization in business is the application of international accounting standards [11]. This is especially significant in companies that operate mainly as agricultural companies and that make their living in primary agricultural production [12-15], where the application of internal controls of all production processes is becoming more pronounced.

Thus observed, the existence of general conditions related to business in agricultural production essentially leads to changes in the general socio-economic conditions of business in the economy as a whole [16].

In agricultural production and production that accompanies agriculture, it is necessary to take into account real financial reporting, which is pointed out by numerous authors such as [17], which essentially represents only the first stage of successful management.

The second stage is the disposal of documentation, i.e. archiving of documentation, which was the basis for the preparati on of this study by the author.

Therefore, the authors of the study basically had the idea to observe the archiving of documentation in agricultural companies, but also to observe the forms of control introduced in them from the point of view of general security of documentation disposal in the mentioned companies.

MATERIALS AND METHODS

To prepare this study, the authors conducted a survey in 144 companies that basically operate as agricultural companies. The survey was conducted with the aim of determining the existence of possible differences between electronic archiving of documentation in agricultural companies and the classic form of archiving documentation.

The aim of the author was to determine the existence of possible differences between the two forms of archiving documentation in the surveyed companies. The existence of the introduced system of financial control and management was determined in 79 agricultural companies, and the introduced systems of establishing control in the company were not found in 65 companies.

The research was done in the first half of 2021. Sim surveyed companies were guaranteed anonymity and it was guaranteed that the generals of the company would not be shown, but the obtained data would be used for the purpose of publishing scientific papers and for the purposes of this study.

The statistical package SPSS IBM 22.0 was used for data processing.

The authors used the application of descriptive statistical methods, which were intended for different types of levels of measurement of variables (Phi / Cramer correlation coefficient).

RESEARCH RESULTS

For the purpose of strengthening attitudes regarding the archiving of documentation, the authors of the study used a descriptive presentation of the obtained survey results. The starting point in the research was the existence of two forms of archiving documentation, namely: classical archiving of documentation and electronic archiving of documentation (a new model of archiving). The obtained results are presented by the authors in the form of Table 1.

Strengthening of attitudes was done by applying the representation using the Phi / Cramer correlation coefficient, and the results of statistical significance are presented by the authors in the form of a tabular presentation in Table 2.

Table 1. Descriptive presentation of the two analyzed forms of archivin documentation in agricultural enterprises in relation to the two forms of introduced control in enterprises

		Control form		Total
		Financial management and control	Lack of control	
Form of archiving	Electronic office	77	3	80
	Classic office	2	62	64
Total		79	65	144

Source: authors' calculation (2021).

Table 2: Display of Phi/Cramer's correlation coefficient

	The correlation coefficient	Statistical significance of the coefficient
Phi	.930	.000
Cramer's V	.930	.000
Total number of surveyed companies	144	

Source: authors' calculation (2021).

DISCUSSION

The starting point in this study was that archiving of documents works equally well in companies if a system of financial management and control is introduced, as well as that in such companies in most cases archiving is done in electronic form (a new way of archiving documentation), in relation to another form of archiving in companies in which the system of financial management and control has not been introduced, and in such companies the documentation is stored and archived through a classically organized office (company office).

The results of the research indicate that there is a statistical significance expressed through Cramer's correlation coefficient (p = .000), i.e. there are pronounced differences in the security of documentation archiving in the mentioned two forms of organization in companies.

CONCLUSION

Based on the obtained research results, it can be concluded that there is a really big difference between the two forms of archiving organization in agricultural enterprises in the Republic of Serbia. A new way of organizing archiving in agricultural companies most often occurs with companies that have introduced electronic archiving of documentation, but also with which there is an introduced system of financial management and control. The old way of archiving is present in agricultural companies that do not have introduced controls. The authors of the study indicate that the results of the research are such that there is a pronounced statistical significance visible in Table 2 by showing Cramer's correlation coefficient (p = .000), i.e. there are significant differences in the security of archiving documentation for agricultural enterprises that have introduced one form of control in their business. and forms of archiving documentation.

Disclosure statement
No potential conflict of interest was reported by the Authors.

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ZNAČAJ ELEKTRONSKOG ČUVANJA DOKUMENTACIJE U POLJOPRIVREDNIM PREDUZEĆIMA U REPUBLICI SRBIJI

Dejan Jeremić[1], Slobodan Stanojević[2]

[1]Visoka škola za menadžment i ekonomiju, Karadjordjeva 52, 34000 Kragujevac Srbija,
[2]Fakultet za primenjeni menadžment, ekonomiju i finansije, Jevrejska 24-1, 11000 Beograd, Srbija.

Sažetak: U ovoj studiji autori ukazuju na značaj arhiviranja dokumentacije u poljoprivrednim preduzećima u Republici Srbiji. Cilj studije bio je da ukaže na značaj novog pristupa (primeni elektronskog arhiviranja) u poljoprivrednim preduzećima. To je od velike važnosti jer dokumentacija je osnov za finansijsko izveštavanje i finansijsko stabilno upravljanje u preduzeću.
Istraživanje je sprovedeno u 144 poljoprivredna preduzeća i utvrdili smo da je finansijsko upravljanje i kontrola uvedena u 79 preduzeća, a da nedovoljan nivo kontrole na nivou preduzeća je prisutan u 65 preduzeća.
Prikazom Phi-Cramer koeficijenta korelacije Autori su dokazali postojanje statističke značaja (p = .00) i postizanje sigurnijeg arhiviranja dokumentacije u poljoprivrednim preduzećima koja su uvela sistem finansijskog upravljanja i kontrole u svoje redovno poslovanje.

Ključne reči: *dokumentacija, finansijsko upravljanje i kontrola.*

Prijavljen: *Submitted*:	**29.07.2021.**
Ispravljen: *Revised*:	**18.12.2021.**
Prihvaćen: *Accepted*:	**10.01.2022.**

CIP Каталогизација у публикацији
Народна библиотека Србије, Београд
631(059)
ПОЉОПРИВРЕДНА техника : научни часопис =
Agricultural Engineering : Scientific Journal /
одговорни уредник Мићо В. Ољача – Год. 1, бр. 1
(1963)- . Београд; Земун : Институт за пољопривредну
технику, 1963 - Београд. (Штампарија: DUGA MOTIV ,
11030 Београд). - 25 цм
Тромесечно. – Прекид у излажењу од 1987-1997. године
ISSN 0554-5587 = Пољопривредна техника
COBISS.SR-ID 16398594