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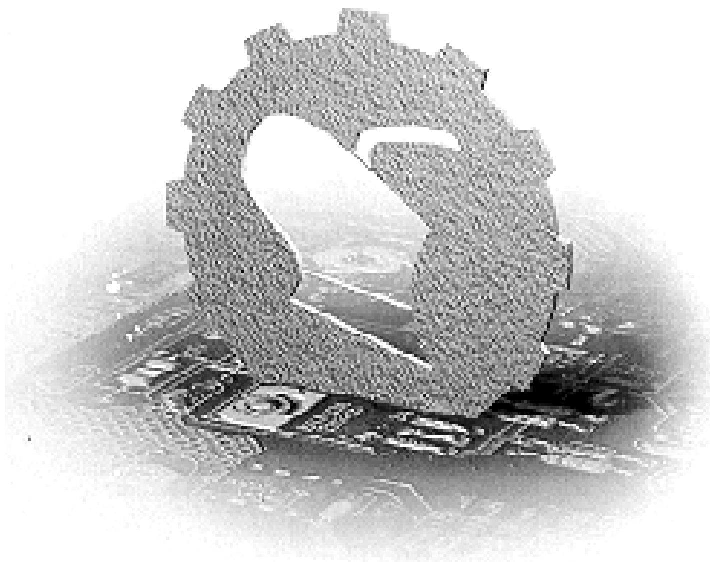

УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
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Контакт подаци уредништва ***(Contact)***
11080 Београд-Земун, Немањина 6, тел. (011)2194-606, 2199-621, факс: 3163-317, 2193-659, e-mail: gogi@agrif.bg.ac.rs, жиро рачун: 840-1872666-79.

11080 Belgrade-Zemun, str. Nemanjina No. 6, Tel. 2194-606, 2199-621, fax: 3163-317, 2193-659, e-mail: gogi@agrif.bg.ac.rs , Account: 840-1872666-79

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EFFECT OF A POLYMER ON MITIGATING AMMONIA EMISSION FROM LIQUID DAIRY MANURE

Lide Chen*, Sai Krishna Yadanaparthi

University of Idaho, College of Agricultural and Life Sciences,
Department of Biological and Agricultural Engineering, Moscow, USA

Abstract: Reducing ammonia (NH_3) emissions from manure has been a great interest for academic, regulators, dairy farmers, and the general public. Fresh liquid dairy manure was collected from a dairy central pit. A polymer (MTM^{TM}) was tested at five different doses to determine if the polymer had any effects on reducing NH_3 emission from the manure. Ogawa NH_3 passive samplers were used to trap NH_3 emitted from the manure for two, four, six, eight, 12, and 24 hours during two separate tests, respectively. Samples collected via the passive samplers were analyzed for ammonium-N (NH_4-N) concentrations by a QuickChem 8500 system. Manure pH values were monitored before and after applying the polymer to the manure. The average concentration reductions of NH_4-N in the extractant were 8.1%, 20.7%, 36.5%, 54.5%, and 88.2% for the polymer Treatments 1 to 5 over the entire test period, respectively. Statistically significant differences of the NH_4-N concentration and manure pH were detected between the treatments and controls. However, a lower dose treatment (0.5 ml polymer/5 l manure) did not show significant differences of the NH_4-N concentration and pH from control for the two-, four-, six-, and eight-hour samples, but showed significant differences for both the 12- and 24-hour samples. The test results have shown that a higher dose of polymer led to a lower manure pH and a lower NH_3 emission. Further studies are needed to test if the pH adjustment was the only mechanism for reducing NH_3 emission or other effects existed as well.

Key words: *ammonia, emission, emission reduction, dairy manure, polymer*

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* Corresponding author. E-mail: lchen@uidaho.edu

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INTRODUCTION

The emission of ammonia (NH_3) from dairy manure is not only a loss of valuable nitrogen, but also an air quality concern because NH_3 plays a role in the formation of ammonium sulfate which constitutes the bulk of airborne particulate matter of less than 2.5 μm, which has been a serious concern for causing respiratory diseases at higher concentrations [1-5]. In addition, subsequent deposition of NH_3 can lead to damaged vegetation [6], reduced biodiversity of natural ecosystems [7], and the nitrification and eutrophication of water bodies [8]. Given its adverse economic and environmental impacts, reducing NH_3 emissions from manure has been a great interest for academic, regulators, dairy farmers, environmentalists, and the general public. Several approaches have been suggested and evaluated for mitigating NH_3 emissions from excreted animal manure which include reducing nitrogen excretion through manipulating feeding rations, reducing volatile NH_3 in the manure, and segregating urine from feces to reduce contact between urease and urine [3]. Methods for reducing the more volatile NH_3 in manure include the reduction of manure pH, which shifts the equilibrium in favor of ammonium (NH_4^+) over NH_3; use of other chemical additives that bind NH_4-N; and use of biological nitrification-denitrification to convert NH_4^+ into non-volatile N-species such as nitrite, nitrate, or gaseous nitrogen. Other methods for mitigating NH_3 emissions target emitting surfaces, and include capturing air using physical covers and treating the captured air using bio-filters or/and scrubbers, and manure subsurface injection during land application. Manure collection facility designs and appropriate facility management are also essential for abating NH_3 emissions [3].

A number of techniques have been used for the determination of NH_3 in the atmosphere. These methods include direct chemiluminescence [9], filter packs [10], denuders [11], acid scrubbers [11] and photoacoustic analyzer [12]. In passive samplers, the atmospheric compound of interest diffuses to a reactive surface, which chemically traps the gas. Passive samplers have been successfully used to determine NH_3 in ambient air [4,13,14].

More Than Manure (MTM™), a maleic-itaconic copolymer product, was developed by Specialty Fertilizer Products (Leawood, KS) for improving manure fertilizer use and reducing ammonia emission from manure. The objective of this study was to evaluate the effect of the polymer (MTM™) on mitigating NH_3 emissions, by using NH_3 passive samplers, from liquid dairy manure within 24 hours after applying the polymer.

MATERIALS AND METHODS

Experiment Equipment

Twenty-five five-gallon buckets were used in this study for containing liquid dairy manure. Each bucket had a lid on which two 51-cm holes were made for facilitation of placing and removing passive samplers and a pH probe during the tests (Figure 1). The pH probe and pH meter (Figure 2) were purchased from Cole-Parmer and used to monitor dairy manure pH during the tests.

Figure 1. Five-gallon bucket with lid (two 51-cm holes were made on the lid)

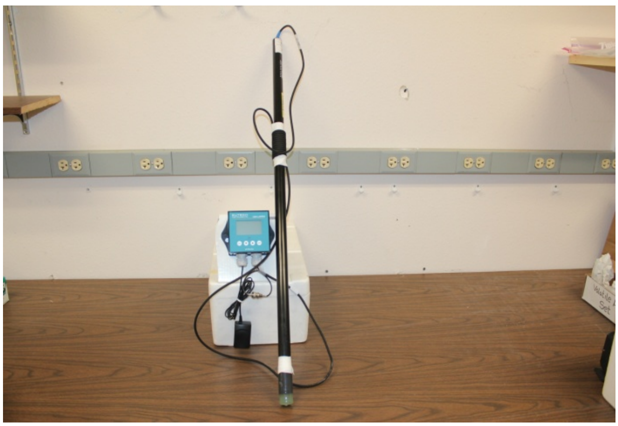


Figure 2. pH probe and pH meter

Ogawa passive NH_3 samplers (Ogawa USA, Inc., Pompano Beach, Florida, Figure 3) were used to determine the time-averaged concentrations of NH_3 in the head space of the five-gallon buckets containing both the polymer treated and untreated (control) liquid dairy manure. The dissembled components of the passive samplers were thoroughly cleaned before placing them into the headspace of the buckets by rinsing with deionized water, soaking in a 1 M HCI (Hydrogen Chloride) bath, rinsing again with deionized water, and then air-drying in a clean hood. The passive sampler filters were prepared by saturating a clean filter with 100 µl of 2% citric acid and air-drying before assembling the samplers. A total of 180 passive NH_3 samplers (figure 3) were prepared separately on April 12, 2012 (90 samplers) and April 26, 2012 (90 samplers) in the USDA Northwest Irrigation and Soil Research Micro laboratory located in Kimberly, Idaho (USDA ARS Kimberly). Assembled samplers were then placed into airtight containers and transported to the Waste Management Laboratory at University of Idaho Twin Falls Research and Extension Center (U-Idaho Twin Falls R&E Center) located in Twin Falls, Idaho for deployment.

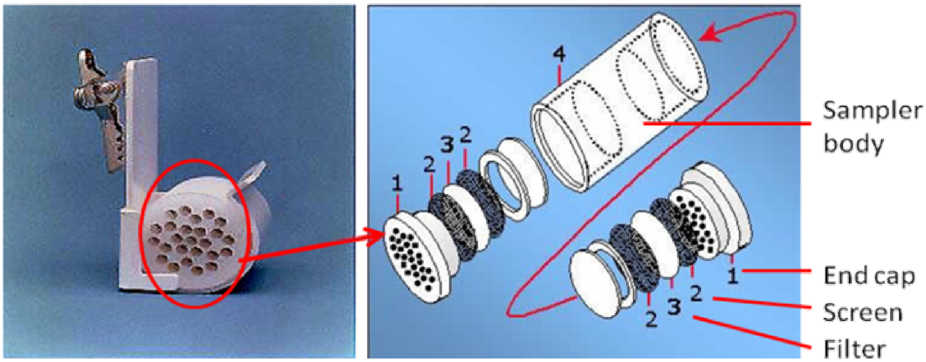


Figure 3. Ogawa Passive sampler (modified from www.ogawausa.com)

A flow-injection analysis system (Quickchem 8500, Lachat Instruments, Milwaukee, WI, Figure 4) was used to analyze NH_4-N extracted from passive sampler filters which trapped NH_3 in the head space of each bucket. The Quickchem 8500 system needs different carrier solutions which were prepared at the USDA ARS Kimberly based on the system's requirements.

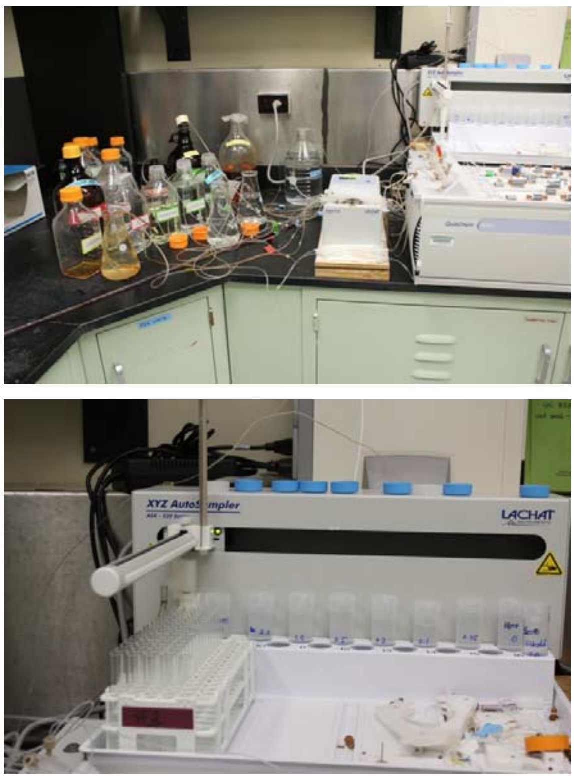


Figure 4. Quickchem 8500 analyzing system,
all carrier solutions (up) and auto sampler of the system (down)

Manure Source and the Polymer

Fresh liquid dairy manure was collected from a commercial dairy in Jerome, Idaho on April 13th and April 27th, 2012, respectively. The dairy was an open lot dairy with flush alleys. All the flushing wastes flowed into a central pit and then went through solid separation processes. After the solid separation, the wastes flowed into a series of lagoons. Liquid dairy manure was collected from the central pit where odor and gas emissions peak. The collected manure was then transported back to the U-Idaho Twin Falls R&E Center. At the U-Idaho Twin Falls R&E Center, the collected manure was well mixed before it was distributed into the five-gallon buckets without any extra pretreatments. The liquid dairy manure pH were 7.94 and 7.46 for the 13th and 27th samples, respectively. The polymer was provided by the J.R. Simplot Agribusiness Company (Boise, ID). The polymer had the following physical and chemical properties:

- Appearance: light yellow to brown liquid with characteristic light odor;
- Chemical Identification: mixture of maleic-itaconic copolymer partial calcium salt and maleic-itaconic copolymer partial ammonium salt, 50% W/W total solids solution in water;
- pH: 3.4;
- Specific gravity: 1.2;
- Freezing range: -5˚C.

Experiment Procedure

Due to a limited number of Ogawa passive samplers available, two separate tests were conducted starting on April 13th and April 27th, 2012, respectively. Well mixed liquid manure was randomly distributed into 25 five-gallon buckets with five liters of manure in each bucket for each of the two tests. A computer program (http://www.random.org/sequences/) was used to generate a series of randomized number. Four of the 25 buckets were randomly chosen based on the series of randomized number to be controls and treatments with five different doses (namely Treatment 1 = T1 = 0.5 ml polymer/5 l manure, Treatment 2 = T2 = 2 ml polymer/5 l manure, Treatment 3 = T3 = 4 ml polymer/5 l manure, Treatment 4 = T4 = 8 ml polymer/5 l manure, and Treatment 5 = T5 = 32 ml polymer/5 l manure) of the polymer, respectively. The polymer doses were based on manufacturer's suggestion. The remaining bucket was used for a time series test. The time series test was for determining if the passive samplers reached their saturation capacities during the test period; therefore, no polymer was applied to the time series test bucket. After pouring manure into the buckets and applying the treatments, all of the 25 buckets were covered with lids. Passive samplers were placed into the head space of each bucket via one of the 51-cm holes. After passive samplers were placed in the headspace of each bucket, all of the buckets were sealed by tape and were kept at the U-Idaho Twin Falls R&E Center during the test periods. The temperature in the U-Idaho Twin Falls R&E Center lab was maintained from 18 to 20˚C during the tests.

During the first test period starting on April 13, 2012, five passive samplers were placed into the time series test bucket. At two, four, six, eight, and 13 hours, a passive sampler was pulled out from the time series test bucket, respectively. Seventy-two passive samplers were placed into the headspaces of the 24 control and treatment buckets with three samplers of each bucket. At two, four, and six hours, a passive sampler was pulled out from the headspace of each bucket, respectively. Right after pulling out the passive samplers, sampler filters were transferred using clean forceps into 15-ml centrifuge tubes and were stored in a refrigerator for later analysis. Manure pH was measured when a passive sampler was pulled out from a bucket. After all of the samples were collected, the centrifuge tubes were brought to the USDA ARS Kimberly for analysis.

During the second test period starting on April 27, 2012, six passive samplers were placed into the time series test bucket. At two, four, six, eight, 12, and 24 hours, a passive sampler was pulled out from the time series test bucket, respectively. Seventy-two passive samplers were placed into the headspaces of the 24 control and treatment buckets with three samplers of each bucket. At eight, 12, and 24 hours, a passive sampler was pulled out from the headspace of each bucket, respectively. Passive sampler collection and pH monitoring were following the same procedure as the first test.

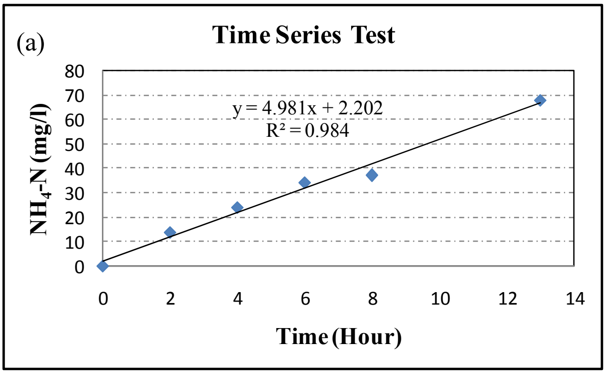
At the USDA ARS Kimberly, the filters in each centrifuge tube were extracted with 5 ml 1 M KCl (Potassium Chloride) for 30 minutes on a reciprocating shaker. The extractant was filtered with 0.45 µm filter discs into 8 ml glass culture tubes. The filtered extractant was then analyzed for NH_4-N via the Quickchem 8500 system according to the system's operating procedure. The QuickChem 8500 system reported NH_4-N concentrations as mg/l. The first test of 77 samples and second test of 78 samples were analyzed on April 15 and 29, 2012, respectively.

Statistical Analysis

The NH_4-N concentrations within the extractant were used to evaluate if there was any effects of the polymer on mitigating NH_3 emission from liquid dairy manure and used to compare if there were any differences between the controls and treatments in this paper; therefore, a higher NH_4-N concentration within the extractant means a higher NH_3 emission from the manure. Ammonium-N and pH data were checked first to eliminate potential outliers using SAS PROC UNIVARIATE. Statistical analyses were conducted using SAS PROC GLM for both pH and NH_4-N data. Statements of statistical significance were based on $P < 0.05$.

RESULTS AND DISCUSSION

The time series test results are shown in Figure 5. The linear relationship between the NH_4-N concentrations and the deployed times indicated that the passive samplers did not reach their saturation status during the test period for both of the tests, which was good. Had the passive samplers reached their saturation, the results would have been compromised.



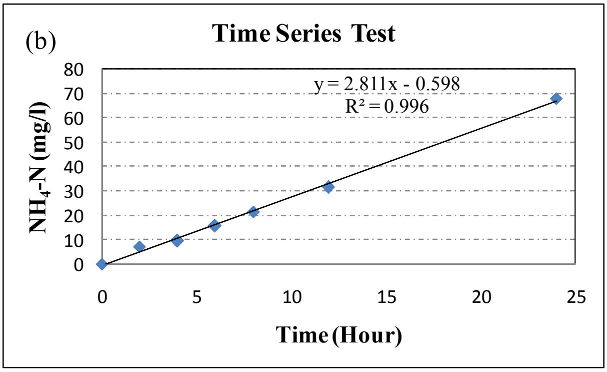


Figure 5. Time series test for (a) first test and (b) second test.

All the NH_4-N and pH data from both the control and treatments are shown in the Tables 1 and 2 for the first and second test, respectively. The concentration reductions of NH_4-N in the extractant, which were defined as (100 × [control concentration-treatment concentration]/control concentration), were 8.1%, 20.7%, 36.5%, 54.5%, and 88.2% for Treatments 1 to 5 over the entire test period, respectively.

Table 1. First test results
(C = Control = without polymer treatment, Treatment 1 = T1 = 0.5 ml polymer/5 l manure, Treatment 2 = T2 = 2 ml polymer/5 l manure, Treatment 3 = T3 = 4 ml polymer/5 l manure, Treatment 4 = T4 = 8 ml polymer/5 l manure, and Treatment 5 = T5 = 32 ml polymer/5 l manure)

Treatment	Ave. ± SD* for NH_4-N (mg/l)			Ave. ± SD* for pH		
	2 Hours	4 Hours	6 Hours	2 Hours	4 Hours	6 Hours
C	13.28 ± 1.52	27.20 ± 4.84	38.88 ± 5.28	7.94 ± 0.03	7.94 ± 0.03	7.94 ± 0.06
T1	12.78 ± 1.69	24.05 ± 1.19	36.88 ± 3.57	7.88 ± 0.04	7.88 ± 0.03	7.88 ± 0.04
T2	12.08 ± 0.87	20.88 ± 0.70	29.53 ± 1.04	7.52 ± 0.08	7.53 ± 0.07	7.55 ± 0.05
T3	9.54 ± 1.86	17.65 ± 2.26	25.15 ± 3.84	7.19 ± 0.12	7.31 ± 0.11	7.33 ± 0.09
T4	6.67 ± 1.51	12.18 ± 1.39	17.68 ± 1.42	6.98 ± 0.04	7.01 ± 0.06	7.04 ± 0.05
T5	2.05 ± 0.58	3.64 ± 0.17	5.19 ± 0.34	6.24 ± 0.05	6.31 ± 0.01	6.34 ± 0.03

*Based on four samples.

Table 2. Second test results
(C = Control = without polymer treatment, Treatment 1 = T1 = 0.5 ml polymer/5 l manure, Treatment 2 = T2 = 2 ml polymer/5 l manure, Treatment 3 = T3 = 4 ml polymer/5 l manure, Treatment 4 = T4 = 8 ml polymer/5 l manure, and Treatment 5 = T5 = 32 ml polymer/5 l manure).

Treatment	Ave. ± SD* for NH_4-N (mg/l)			Ave. ± SD* for pH		
	8 Hours	12 Hours	24 Hours	8 Hours	12 Hours	24 Hours
C	21.93 ± 1.22	33.83 ± 1.07	75.45 ± 1.77	7.46± 0.03	7.46 ± 0.02	7.37 ± 0.02
T1	19.90 ± 1.50	29.90 ± 2.77	69.93 ± 4.06	7.40 ± 0.02	7.40 ± 0.02	7.29 ± 0.01
T2	15.63 ± 2.73	26.73 ± 3.12	61.93 ± 4.43	7.22 ± 0.02	7.25 ± 0.02	7.18 ± 0.03
T3	12.68 ± 1.09	20.33 ± 1.36	46.40 ± 4.83	7.02 ± 0.02	7.06 ± 0.03	7.02 ± 0.02
T4	9.85 ± 0.76	14.38 ± 1.29	34.03 ± 2.20	6.82 ± 0.02	6.88 ± 0.01	6.86 ± 0.02
T5	1.99 ± 0.49	2.91 ± 0.28	8.47 ± 1.67	6.11 ± 0.08	6.19 ± 0.03	6.23 ± 0.02

*Based on four samples.

Test data at all the sampling time points (2, 4, 6, 8, 12, and 24 hours) from both the first and second test showed a reduction trend of NH_3 emission with higher doses of the polymer (Figures 6 and 7).

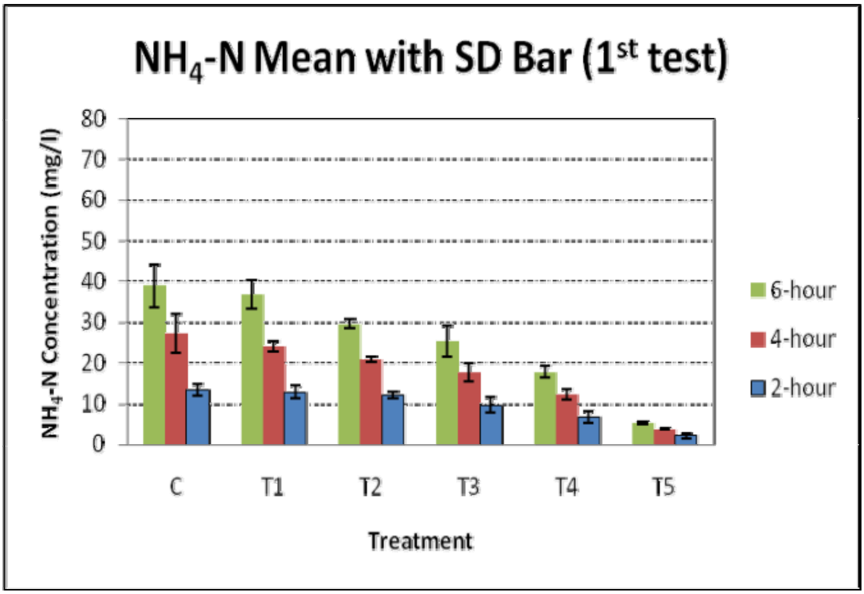


Figure 6. Ammonium-N concentration vs. treatment for the first test (C = Control = without polymer treatment, Treatment 1 = T1 = 0.5 ml polymer/5 l manure, Treatment 2 = T2 = 2 ml polymer/5 l manure, Treatment 3 = T3 = 4 ml polymer/5 l manure, Treatment 4 = T4 = 8 ml polymer/5 l manure, and Treatment 5 = T5 = 32 ml polymer/5 l manure).

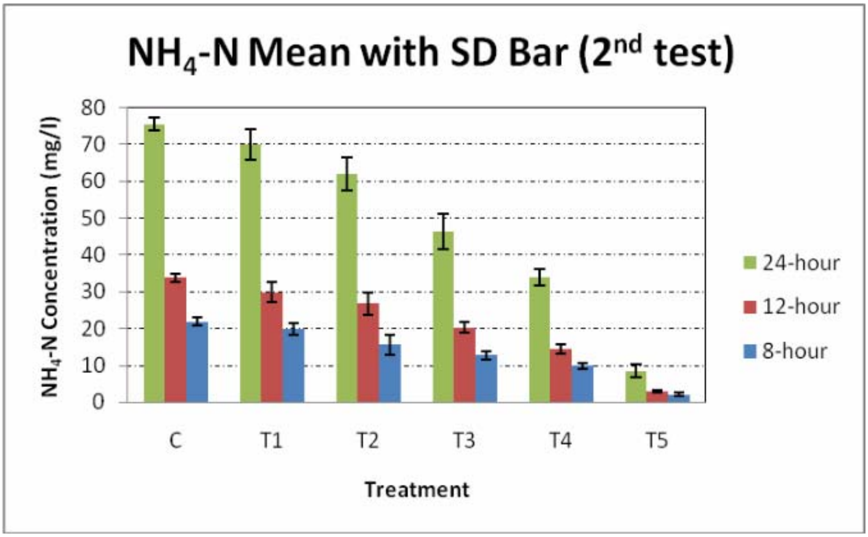


Figure 7. Ammonium-N concentration vs. treatment for the second test (C = Control = without polymer treatment, Treatment 1 = T1 = 0.5 ml polymer/5 l manure, Treatment 2 = T2 = 2 ml polymer/5 l manure, Treatment 3 = T3 = 4 ml polymer/5 l manure, Treatment 4 = T4 = 8 ml polymer/5 l manure, and Treatment 5 = T5 = 32 ml polymer/5 l manure).

For both the first and second test, results showed that a higher pH leaded to a higher NH_3 emission at all the sampling time points (Figures 8 and 9). A correlation analysis between average NH_4-N in the extractant and manure pH showed that there was a strong correlation between NH_3 emission and manure pH. The coefficients of correlation are shown in Table 3.

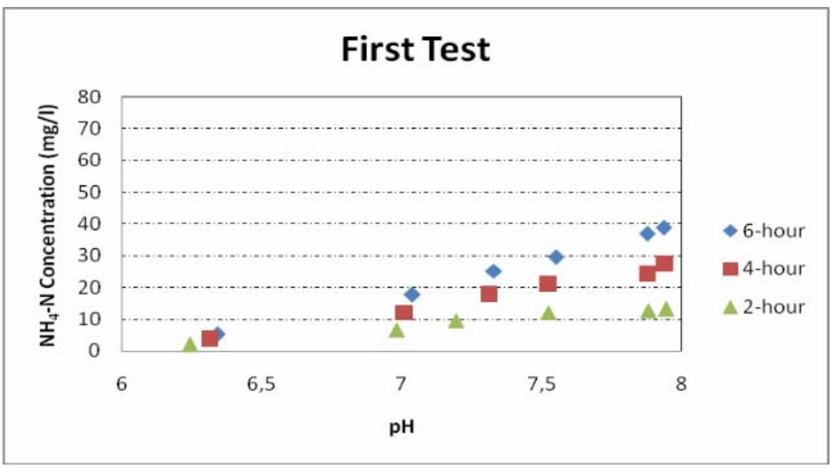


Figure 8. Ammonium-N vs. pH for 2-, 4-, and 6-hour results

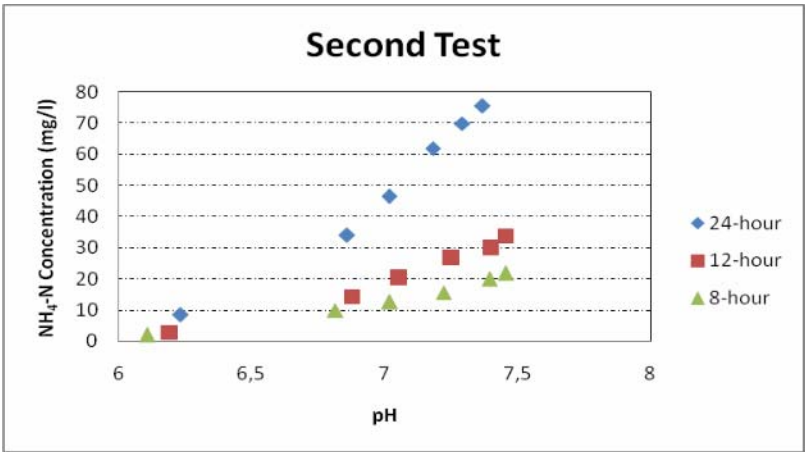


Figure 9. Ammonium-N vs. pH for 8-, 12-, and 24-hour results

Table 3. Coefficient of correlation between average ammonium-N and manure pH

Sampling Time	2-hour	4-hour	6-hour	8-hour	12-hour	24-hour
Coefficient of Correlation	0.98	0.99	1	0.98	0.98	0.98

Ammonia volatilization occurs because NH_4-N in manure is converted to dissolved NH_3 gas, by the reaction:

$$NH_4^+\text{-N} \leftrightarrows NH_{3g} + H^+$$

The reaction produces more NH_{3g} as pH or temperature increases, and as the NH_4-N concentration in manure increases. When the temperature is held constant, pH determines the equilibrium between NH_4^+ and NH_3 in aqueous systems. A lower pH results in a lower proportion of aqueous NH_3, thus leading to a lower potential of NH_3 volatilization. The polymer reduced manure pH at all dose levels tested within the test time period in this study, thus reducing NH_3 emission. The polymer may have other mechanisms leading to mitigation of NH_3 emission such as ammonium binding and/or biological treatments that assimilate and immobilize volatile N or transform volatile N into non-volatile inorganic N. A potential evidence was that Treatment 2 showed significant differences of NH_4-N from control for longer time samples (4-, 6-, 8-, 12-, and 24-hour), but not for 2-hour samples. One possible reason was that the polymer may have the capability of immobilization of volatile N compounds or may manipulate microbial activity or control enzyme activities related to NH_3 emission, but these effects need a longer time. However, no other N-species in the manure were monitored in this study. More studies are needed to draw a conclusion.

Based on the SAS results for NH_4-N (Table 4), Treatments 3, 4, and 5 showed statistically significant differences of NH_4-N concentrations from control and the other treatments for all the 2-, 4-, 6-, 8-, 12-, and 24-hour samples. Treatment 2 showed significant differences of NH_4-N concentrations from control and the other treatments for the 4-, 6-, 8-, 12-, and 24-hour samples, but Treatment 2 did not show significant differences from control for 2-hour samples. Treatment 1 showed significant differences of NH_4-N concentrations from control and the other treatment levels for the 12- and 24-hour samples, but Treatment 1 did not show significant differences from control for the 2-, 4-, 6-, and 8-hour samples.

Again, this may be an indication that the polymer contributed to mitigation of ammonia emission in other ways than just reducing manure pH.

Table 4. SAS results for ammonium-N
(C = Control = without polymer treatment, Treatment 1 = T1 = 0.5 ml polymer/5 l manure, Treatment 2 = T2 = 2 ml polymer/5 l manure, Treatment 3 = T3 = 4 ml polymer/5 l manure, Treatment 4 = T4 = 8 ml polymer/5 l manure, and Treatment 5 = T5 = 32 ml polymer/5 l manure). Means with the same letter in the following parenthesis are not significantly different.

Treatment	Mean of NH_4-N (mg/l)					
	First Test			Second Test		
	2-hour	4-hour	6-hour	8-hour	12-hour	24-hour
C	13.3 (A)	27.2 (A)	38.9 (A)	21.9 (A)	33.8 (A)	75.5 (A)
T1	12.8 (A)	24.1 (A)	36.9 (A)	19.9 (A)	29.9 (B)	69.9 (B)
T2	12.1 (A)	20.9 (D)	29.5 (B)	15.7 (B)	26.7 (D)	61.9 (D)
T3	9.5 (B)	17.7 (D)	25.2 (B)	12.7 (D)	20.3 (E)	46.4 (E)
T4	6.7 (D)	12.2 (E)	17.7 (D)	9.9 (E)	14.4 (F)	34.0 (F)
T5	2.0 (E)	3.6 (F)	5.2 (E)	2.0 (F)	2.9 (G)	8.5 (G)

Test data showed that the polymer reduced manure pH. The SAS results for manure pH are shown in Table 5. All the treatments reduced manure pH significantly for the 8-, 12-, and 24-hour samples during the second test. For the first test, all the treatments, except the Treatment 1, showed significant differences of pH between control and the treatments for the 2-, 4-, and 6-hour samples during the first test. Treatment 1 did not show significant differences of pH from control for the 2-, 4- and 6-hour samples. The test data also showed that a lower pH resulted in a lower NH_3 emission which agreed with others results.[15, 16]

Table 5. SAS results for pH
(C = Control = without polymer treatment, Treatment 1 = T1 = 0.5 ml polymer/5 l manure, Treatment 2 = T2 = 2 ml polymer/5 l manure, Treatment 3 = T3 = 4 ml polymer/5 l manure, Treatment 4 = T4 = 8 ml polymer/5 l manure, and Treatment 5 = T5 = 32 ml polymer/5 l manure). Means with the same letter in the following parenthesis are not significantly different.

Treatment	Mean of NH_4-N (mg/l)					
	First Test			Second Test		
	2-hour	4-hour	6-hour	8-hour	12-hour	24-hour
C	7.9 (A)	7.9 (A)	7.9 (A)	7.5 (A)	7.5 (A)	7.4 (A)
T1	7.9 (A)	7.9 (A)	7.9 (A)	7.4 (B)	7.4 (B)	7.3 (B)
T2	7.5 (B)	7.5 (B)	7.5 (B)	7.2 (D)	7.3 (D)	7.2 (D)
T3	7.2 (D)	7.3 (D)	7.3 (D)	7.0 (E)	7.1 (E)	7.0 (E)
T4	7.0 (E)	7.0 (E)	7.0 (E)	6.8 (F)	6.9 (F)	6.9 (F)
T5	6.2 (F)	6.3 (F)	6.3 (F)	6.1 (G)	6.2 (G)	6.2 (G)

CONCLUSIONS

The results obtained from this study have shown that mitigation of NH_3 emission from liquid dairy manure can be achieved by using the MTM^{TM} polymer. Developing manure additives that effectively abate NH_3 emission from manure could be a key step toward the goal of mitigating NH_3 emission. The tested polymer showed average concentration reductions of NH_4-N in the extractant were 8.1%, 20.7%, 36.5%, 54.5%, and 88.2% for the polymer Treatments 1 to 5 over the entire test period, respectively. Significant effect on mitigating NH_3 emission from liquid dairy manure within 24 hours after applying the polymer was observed. However, a lower dose treatment (0.5 ml polymer/5 l manure) did not show significant differences of the NH_4-N concentration and pH from control at short time periods (two-, four-, six-, and eight-hour sampling times). The test results have shown that a higher dose of polymer led to a lower manure pH and a lower NH_3 emission. Further studies are needed to test if the pH adjustment was the only mechanism for reducing NH_3 emission or other effects existed as well.

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EFEKAT POLIMERA NA SMANJENJE EMISIJE AMONIJAKA IZ TEČNOG GOVEĐEG STAJNJAKA

Lide Chen, Sai Krishna Yadanaparthi

Univerzitet Idaho, Fakultet za poljoprivredu i prirodne nauke, Institut za biološko i poljoprivredno inženjerstvo, Moscow, SAD

Sažetak: Smanjenje emisije amonijaka (NH_3) iz tečnog stajnjaka je od velikog interesa za istraživače, nadzorne organe, vlasnike farmi muznih krava i javnost uopšte. Svež tečni stajnjak je skupljan iz centralnog kolektora na farmi. Polimer (MTM^{TM}) je testiran u pet različitih doza da bi se ispitao uticaj polimera na smanjenje emisije NH_3 iz đubriva. Ogawa NH_3 pasivni sakupljači uzoraka su korišćeni za sakupljanje NH_3 oslobođenog iz đubriva tokom perioda od 2, 4, 6, 8, 12 i 24 časa, u dva odvojena testa. U uzorcima sakupljenim pasivnim sakupljačima analizirana je koncentracija amonijaka-N (NH_4-N) korišćenjem aparata QuickChem 8500. pH vrednosti su praćene pre i posle dodavanja polimera u đubrivo. Prosečno smanjenje koncentracije NH_4-N u ekstraktantu je bilo 8.1%, 20.7%, 36.5%, 54.5% i 88.2% pri tretiranju različitim dozama polimera u testovima 1 do 5. Statistički značajne razlike u koncentraciji NH_4-N i pH vrednosti đubriva su uočene upoređivanjem tretiranja različitim dozama i u različitim vremenskim periodima. Međutim, tretiranje nižim dozama polimera (0.5 ml polimera na 5 l đubriva) nije dovelo do značajnog smanjenja u koncentraciji NH_4-N i pH vrednosti u kontrolnim uzorcima izmerenim posle 2, 4, 6 i 8 časova, ali je dovelo do značajne razlike između uzoraka izmerenih posle 12 i 24 časa. Rezultati ispitivanja su pokazali da više doze polimera dovode do niže pH vrednosti đubriva i smanjenja emisije NH_3. Dalja ispitivanja su neophodna da bi se ispitalo da li je podešavanje pH vrednosti jedini mehanizam za smanjenje emisije NH_3 ili postoje i drugi mehanizmi.

Ključne reči: *amonijak, emisija, smanjenje emisije, goveđi stajnjak, polimer*

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EFFECT OF AGRICULTURAL NAVIGATION WITHOUT RTK CORRECTION ON SPRING SOWING

Petar Petrov*, Stoyan Ishpekov, Georgy Komitov, Teodora Kachorova

Agricultural University, Department of Agricultural Machinery, Plovdiv, Bulgaria

Abstract: It is carried out a comparative investigation of seed drill guiding accuracy in two ways. In the first way the drill is guided by a conventional disk marker and in the second way - by agricultural navigation without RTK correction. It is found that the usage of agricultural navigation lead to more straight rows and reduction of the fuel consumption, but the distance between drill tracks exceeds the row width about 26 %, because of low level of navigation accuracy.

Key words: *seed drill, agricultural navigation, sowing, fuel consumption*

INTRODUCTION

The sowing, spraying and soil fertilizing need of precisely machinery guiding on the field. For the purpose are used conventional disk markers. Unfortunately, their usage is inefficient on machinery with big working width, even it is impossible in majority of cases.

The GPS technology offers another way of machinery guiding on the field. The existing navigation systems have the following level of accuracy: 15-20 cm; 7,5-12,5 cm; 5-10 cm and 2,5 cm [1]. The navigation guiding without RTK correction ensures only the low level of mentioned accuracy and is free of charge for the farmers. They have to pay for higher levels of accuracy, but no every one may afford it.

The purpose of the investigation is to determine the real effect of an agricultural navigation without RTK correction on guiding accuracy of a seed drill.

* Corresponding author. E-mail: poliev@abv.bg

We would like to express our gratitude to farmer Venelin Dillgiansky, who created excellent conditions for conducting the experimental work ensuring fields and equipment.

MATERIAL AND METHODS

The investigation is carried out during sowing of an earth-up crop, because this operation requires the highest accuracy of seed drill guiding. It is compared the seed drill guiding in two running ways. In the first way the seed drill is running as it is shown on Figure 1. The drill is guided by agricultural navigation with "*Ag*GPSAutopilot™" [1]. In the second way the machine is guiding through a disk marker and the runs follow one after another (Fig. 2).

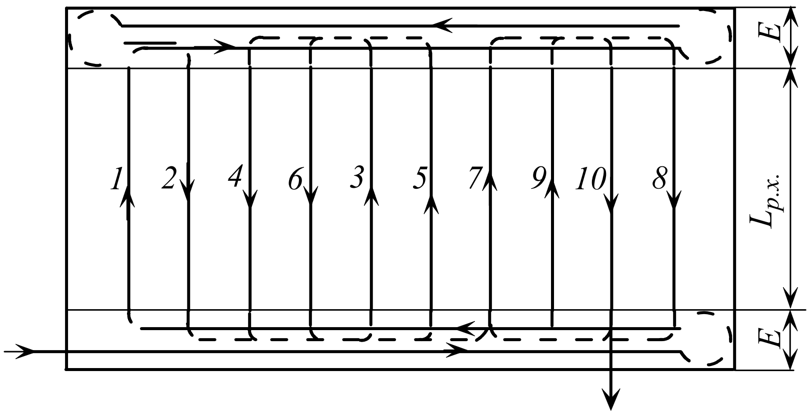

Figure 1. First running way

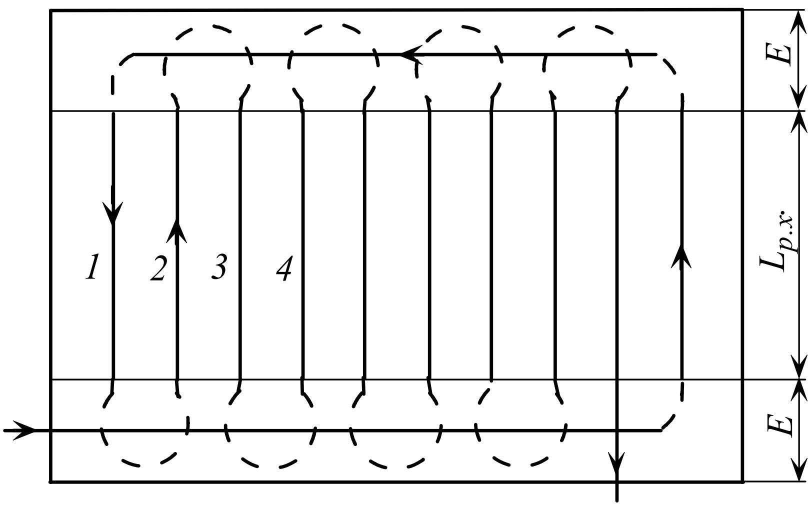

Figure 2. Second running way

It is measured the durations of every working runs and the turns on both sides of the field. The fuel consumption for indicated running ways is also registered [2, 3].

After crop sprouting it is measured the distance between drill tracks in more than 100 points along the working run. In that way are formed samples for calculating statistical and quality indices of the investigated process. The measurements are doing in three replications on different drill tracks for the both running ways.

The experimental data are used for calculating both statistic estimations:

- Mean value - $\overline{x}$;
- Standard deviation - σ.

For each experimental sample is drawn the autocorrelation function. For the process quality evaluation are calculated the following indices [4]:

- Potential capability:

$$C_p = \frac{USL - LSL}{6\sigma} \tag{1}$$

where:

USL is the upper specification limit

$$USL = \overline{x} + 0{,}729\left(x_{max} - x_{min}\right) \tag{2}$$

LSL - the lower specification limit

$$LSL = \overline{x} - 0{,}729\left(x_{max} - x_{min}\right) \tag{3}$$

- Lower potential capability:

$$C_{pl} = \frac{\overline{x} - LSL}{3\sigma} \tag{4}$$

- Upper potential capability:

$$C_{pu} = \frac{USL - \overline{x}}{3\sigma} \tag{5}$$

- Demonstrated excellence

$$C_{pk} = \left(1 - k\right)C_p \tag{6}$$

where:

k is the non-centring correction

$$k = \left[\frac{2\left(D - \overline{x}\right)}{\left(USL - LSL\right)}\right] \tag{7}$$

$$D = \frac{USL + LSL}{2} \tag{8}$$

There are calculated the following operational indices [5]:

- Portion of working runs

For the first running way is applied the formula

$$\varphi = \frac{L_p}{L_p + 0,5C_д + 1,14R_{за} + 2l_a} \tag{9}$$

For the second running way

$$\varphi = \frac{L_p}{L_p + 6R_{за} + 2l_a} \tag{10}$$

where:
L_p [m] - distance of the working run,
l_a [m] - length of the seed drill aggregation,
$R_{за}$ [m] - turn radius,
$C_д$ [m] - distance between two contiguous working runs.

- Productivity of the seed drill unit [ha h^{-1}]:

$$W_h = \frac{3,6.L_p.B_a}{t_p + t_{зав}} \tag{11}$$

where:
B_a [m] - working width of the machine,
t_p [s] - duration for implementation of working runs,
$t_{зав}$ [s] - duration for turn's implementation.

- The portion of working time

$$\tau = \frac{t_p}{t_p + t_{зав}} \tag{12}$$

- The fuel consumption for a unit of area [kg ha^{-1}]:

$$g_c = \frac{1000G}{S} \tag{13}$$

where:
G [kg] - expended fuel,
S [ha] - cropping area.

RESULTS AND DISCUSSION

The experiments are carried out with tractor Jon Deer DJ-6530 and seed-drill Monoseed - RABE 8230 during sunflower sowing.

In the table 1 is seen that the mean distance between boundary rows and the assigned value is 26,2 % for navigation guiding. This deviation is 0,7 % for guiding through markers. The great difference is due to the low accuracy level of used navigation system mainly.

Table 1. Descriptive statistics for the distance between boundary rows

Indices	*Seed-drill guiding way*	
	through navigation	*through markers*
Mean value, $\overline{x}$ *, [cm]*	*88,34*	*69,50*
Minimal value, x_{min}*, [cm]*	*77*	*25*
Maximal value, x_{max}*, [cm]*	*110*	*84*
Standard deviation - σ*, [cm]*	*6,6731*	*17,8024*

However, the standard deviation of the same distances is 2,67 times lower for navigation guiding, in comparison with marker guiding. This means that navigation guiding causes more rectilinear rows.

This conclusion is also confirmed by autocorrelation functions for the drill tracks distances (Fig. 3 and 4). The function gets quiet more lightly for first way of guiding and does not grow quiet at all for second guiding way. These results prove that the navigation assists to more sustainable way of seed-drill guiding.

The potential capability C_p is the simplest and most straightforward indicator of the process capability. Its value for navigation guiding is 49 % higher than for guiding with markers (Tab. 2). The potential capability values also show that about 20 % of measured drill tracks distances for guiding with markers are out of the range between *USL* and *LSL*. Those conclusions are valid only if the investigated processes are centred, which have to evaluate.

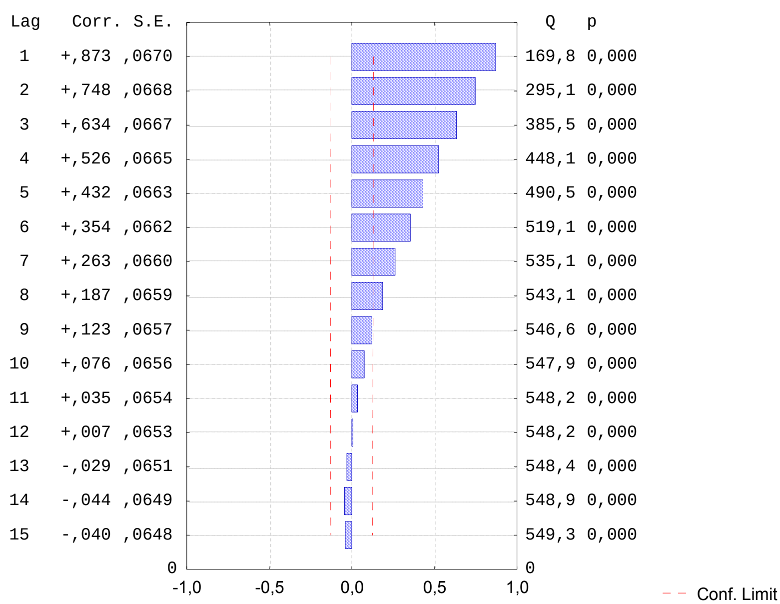

Figure 3. Autocorrelation function of seed-drill tracks distances for navigation guiding.

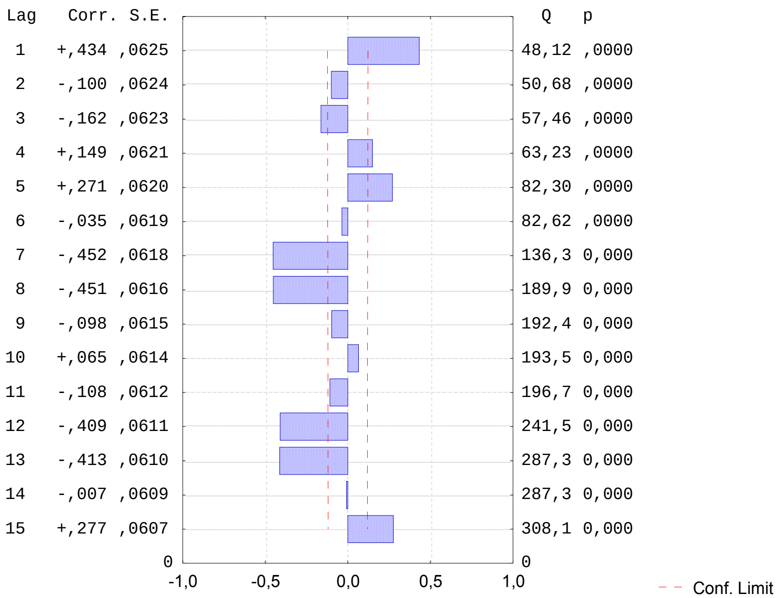

Figure 4. Autocorrelation function of seed-drill tracks distances for guiding with markers.

Table 2. Qualitative indices for the distance between boundary rows

Sample Indices	*Seed-drill guiding way*	
	through navigation	*through markers*
Potential capability - C_p	*1,202*	*0,805*
Upper potential capability - C_{pu} *for different samples*	*0,42 ÷ 2,82*	*0,36 ÷ 3,68*
Lower potential capability - C_{pl} *for different samples*	*0,42 ÷ 0,65*	*0,36 ÷ 0,68*
Demonstrated excellence - $C_{p\kappa}$	*1,08*	*0,76*

The lower and upper potential capability C_{pl}, C_{pu} allow to evaluate whether the observed investigated process is centred or not. The formulas above show that, if these values are not identical each other, then the process is not centred. Results in table 2 show that the processes are not centred.

The non-centring correction k allows adjusting C_p for the effect of non-centring. If the process is perfectly centred, then k is equal to zero, and C_{pk} is equal to C_p. However, as the process drifts from the target specification, k increases and C_{pk} becomes smaller than C_p. Demonstrated excellence values - $C_{p\kappa}$ for navigation guiding are higher than guiding with markers (Tab. 2). Thus the navigation guiding has better capability of the quality for the investigated processes.

Operational indices through marker guiding are better than navigation guiding (Tab. 3). This is because of accepting the shuttle running way. Obviously, the usage of agriculture navigation without RTK correction, for machines with small working width, does not change the operational indices considerably. Its positive effect consist of decreasing the fuel consumption with 18,7 %. That is because the markers are not used, which decrease the seed-drill resistance. Moreover, they require additional time for lifting and dropping. The fuel consumption at the second running way is higher, because of steering with smaller turn radius, which increases the draw resistance of the seed-drill unit.

Table 3. Operation indices

Indices	*Seed-drill guiding way*	
	through navigation	*through markers*
Average length of the working run, [m]	*289,07*	*247,92*
Average length of the turn, [m]	*56,23*	*34,58*
Portion of working runs φ	*0,802*	*0,987*
Productivity W_h *, [ha/h]*	*4,63*	*4,962*
Portion of working time, τ	*0,690*	*0,745*
Fuel consumption, g_c *, [kg/ha]*	*3,0*	*3,56*

Obviously, the precisely agriculture operations, such as the sowing of the earth-up crops, require more accurately seed-drill guiding. This could be accomplished with earth ground RTK network or local stations with 2,5 cm accuracy level achieving.

CONCLUSIONS

1. The smaller deviations of the boundary row space during navigation guiding, determine more straight rows. They give the opportunity to decrease the protection zone during the earth up processing.
2. The usage of agriculture navigation decreases the fuel consumption, because of the opportunity of applying runways that are more rational and dropping out the necessity of disk markers.
3. The boundary row space is wider than the assigned value with 26 % for navigation seed-drill guiding. This is because of the low accuracy level of used navigation system mainly. If it is used a earth ground RTK network or local stations with 2,5 cm accuracy level, the results would be better.

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EFIKASNOST POLJOPRIVREDNE NAVIGACIJE BEZ RTK KOREKCIJE U PROLEĆNOJ SETVI

Petar Petrov, Stoyan Ishpekov, Georgy Komitov, Teodora Kachorova

Poljoprivredni Univerzitet, Institut za poljoprivredne mašine, Plovdiv, Bugarska

Sažetak: Uporedno ispitivanje preciznosti setvene navigacije je izvedeno na dva načina. U prvom testu sejalica je navođena konveniconalno upotrebom diskosnog markera, a u drugom testu putem poljoprivredne navigacije bez RTK korekcije. Utvrđeno je da upotreba poljoprivredne navigacije vodi do pravilnijih redova i smanjenja potrošnje goriva, ali i da razmak između prohoda sejalice prekoračuje širinu između redova za oko 26% zbog niske preciznosti navigacije.

Ključne reči: sejalica, poljoprivredna navigacija, setva, potrošnja goriva

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Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
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RESPIRATORY BEHAVIOUR OF MATURE LIGHT GREEN GUAVA (*Psidium guajava L.*) UNDER CLOSED SYSTEM

Ranjeet Singh[*], Saroj Kumar Giri, Sitaram D. Kulkarni

Central Institute of Agricultural Engineering, Agro-Produce Processing Division, Nabi Bagh, Bhopal, India

Abstract: Respiratory behavior is an important aspect in designing and operating systems such as controlled and modified atmosphere storage that will extend the shelf life of the perishable produce. The respiration rate and respiratory quotient of fresh Guava (*Psidium guajava* L. cv. 'Safeda') fruit harvested at the mature light-green stage were determined under closed system at 5, 10, 15, 20, 25 and 35°C (ambient) temperatures. The respiration rate based on carbon dioxide production in aerobic condition decreased about 46% relative to air atmosphere. However the oxygen consumption sharply reduced to 31% relative to air atmosphere at 25°C temperature. The results suggest that, the respiration rate of Guava increased with temperature and decrease with storage time. Results of the study can be applied to design suitable packaging system for shelf life extension of Guava.

Keywords: *Guava fruit, physic-chemical properties, respiration rate, respiratory quotient.*

INTRODUCTION

Guava (*Psidium guajava* L.) is a commercially important fruit crop in Brazil, Mexico, India and many other tropical countries. Short postharvest life, high susceptibility to chilling, mechanical damage and pathogens limit its distribution to the domestic markets [2]. The significance of respiration in extending the shelf-life of fresh fruits and vegetables stems from the fact that there exists an inverse relationship between respiration rate and the shelf-life of the commodity [3]. Respiration rate, which is

[*] Corresponding author. E-mail: razi100@rediffmail.com

commonly expressed as rate of O_2 consumption and/or CO_2 production per unit weight of the commodity, reflects the metabolic activity of the fruit tissue in the form of biochemical changes associated with ripening [4]. Another important parameter associated with respiration is the respiration quotient (RQ). Very high values of the RQ or a sudden shift in RQ value indicate a shift in the respiration cycle to the anaerobic cycle [7]. This helps select appropriate packaging materials when designing modified atmosphere (MA) packaging systems [8], identifying the vital heat in calculation of refrigeration load, select fan size and location for optimal air flow within controlled atmosphere (CA) facilities and formulate appropriate process control for ventilating storage facilities [6]. Thus, the accurate measurement of respiration is an important step in the successful design storage system for horticultural produce like Guava. Keeping in view the above, it is proposed to study the respiratory behavior of green mature Guava 'Safeda' cultivar under closed system at different temperatures.

MATERIALS AND METHODS

Fruit Materials

Guava (*Psidium guajava* L. cv. 'Safeda') fruit harvested at the mature light-green stage from fruit farm of Central Institute of Agricultural Engineering, Nabi-Bagh, Berasia Road, Bhopal for experimentation and study. The Guavas were graded manually to remove damaged, infested and non-uniform fruit. Fruits were selected to insure uniform size, shape and weight for further experimentation

The parameters such as sphericity, fruit volume, true density, were determined objectively in the lab for mature green Guava before start of the respiration rate study as per the method adopted by [9] and [5].

Measurement of rates of respiration

The respiration rate measurement of Guava was done as per the method adopted by [9]. A closed system is used to measure the respiration rate of the green mature Guava (Fig 1). A known weight (1kg) of green mature Guava was filled into air tight glass container of known volume. The container was sealed carefully using vacuum grease. A single hole covered with silicon septum was made in container for measurement of gas concentrations. After packaging, container was kept at different temperature i.e. 5°C, 10°C, 15°C, 20°C, 25°C and 35°C (ambient temperature) at 75% RH in an Environment System (Systec instruments, Draihan LabTech Co. Ltd, UK; Model: GS3/P-898C) and time was recorded (Fig 1).

Respiration rates in terms of O_2 consumption and CO_2 evolution and respiratory quotient (*RQ*) were determined according to the equations (1) and (2) below:

$$R_{O_2} = \frac{(p_{O_2}{}^{in} - p_{O_2}{}^{f})V_V}{100 \times W \times (t^f - t^{in})} \quad \text{and} \quad R_{CO_2} = \frac{(p_{CO_2}{}^{f} - p_{CO_2}{}^{in})V_V}{100 \times W \times (t^f - t^{in})} \qquad (1)$$

where:

P_{O2} [%] - partial pressure of oxygen gas,

P_{CO2} [%] - partial pressure of carbon-dioxide gas,
V_v [ml]- void volume,
W [kg]- weight of the sample,
t [h] - time,
in [-] - "initial",
f [-] - "final".

$$RQ = R_{CO_2} \cdot R_{O_2}^{-1} \quad (2)$$

where:
RQ [-] - respiratory quotient,
R_{O2} [ml·kg^{-1}·h^{-1}] - respiration rate of oxygen gas,
R_{CO2} [ml·kg^{-1}·h^{-1}] - respiration rate of carbon-dioxide gas.

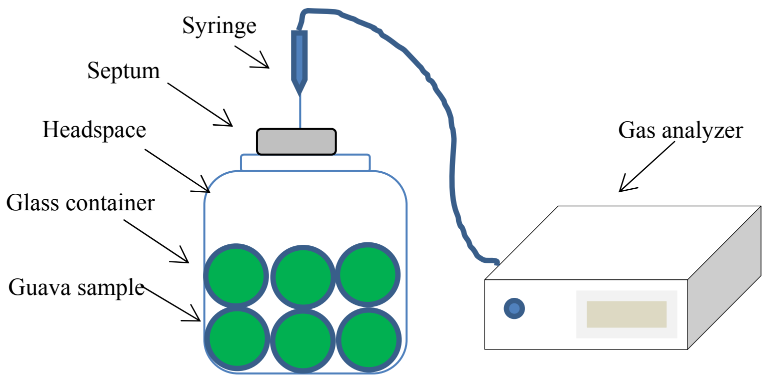


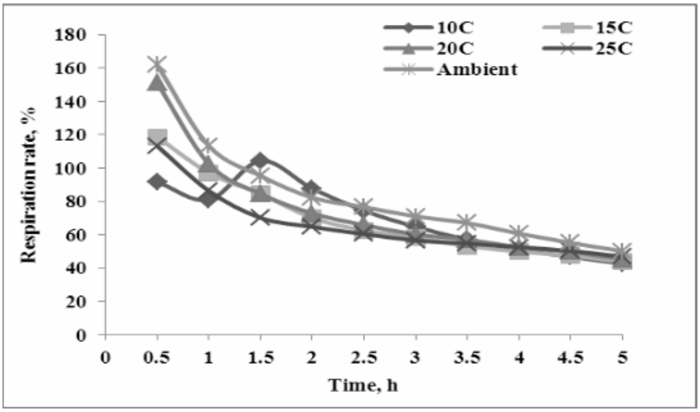
Figure 1. A closed system for respiration rate measurement of the mature light green Guava

RESULTS AND DISCUSSION

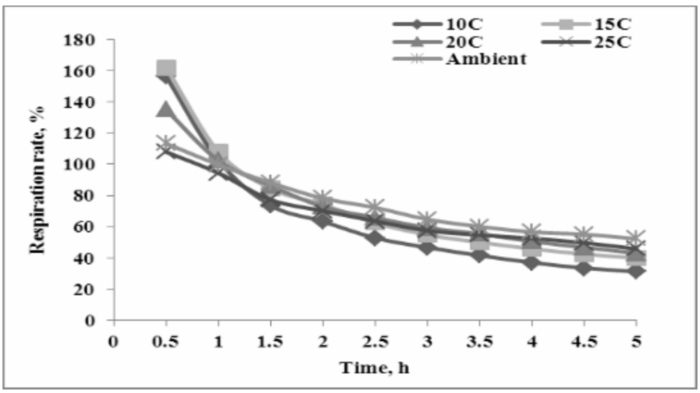
Rate of respiration

The respiration data corresponding to the different temperature indicated that as the temperature increased the respiration progressed at a faster rate. The rate of respiration gradually increased and was higher at the start of the experiment and gradually declined as the storage period prolonged, before becoming almost constant (Fig. 2). The steady-state respiration rate for O_2 consumption was observed to be 31.32, 39.96, 43.20, 45.90 and 52.38 ml·kg^{-1}·h^{-1} at 10°C, 15°C, 20°C, 25°C and 35°C (ambient), respectively. Similarly the steady-state respiration rate for CO_2 evolution were observed to be 42.66, 43.74, 45.36, 46.90 and 50.22 ml·kg^{-1}·h^{-1} at 10°C, 15°C, 20°C, 25°C and 35°C (ambient), respectively. For similar temperature increments, the increase in respiration rate was 2.53, 6.32, 9.93 and 17.72 degree folds for O_2 and 27.58, 37.93, 46.55 and 67.24 degree folds for CO_2 evolution respectively at 15°C, 20°C, 25°C and 35°C (ambient) temperatures.

At all temperatures, the CO_2 consumption rate remained higher than the O_2 evolution rate giving steady-state respiration quotient between 0.7 to 1.70 (Fig 3).



a.



b.

Figure 2. Respiration rate of O_2 depletion (a) and CO_2 evolution (b) for mature lightgreen guava (Safeda) at 5, 10, 15, 20, 25 and 35°C (ambient) temperatures

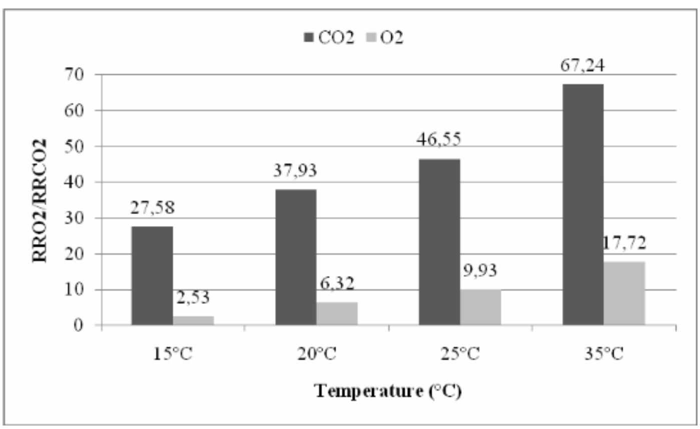


Figure 3. Degree-fold increase in RRO_2/$RRCO_2$ of mature light green guava cv. (Safeda) at different temperature increments

The respiration rate RRO_2 and $RRCO_2$ at all temperature increments observed in this study is in agreement with the respiration range suggested by [5, 8, 9] which is about 42-45 ml $CO_2 \cdot kg^{-1}h^{-1}$. It should be noted that, these values of RO_2 and RCO_2 during respiration rate that were, as previously mentioned, calculated by using normal air rather than using the gas concentration values of modified atmosphere and for the reason, they are more than the respiration rate in previously modified atmosphere under identical temperature.

Respiratory quotient

The ratio of carbon dioxide generation to oxygen consumption will be close to unity when substrate used in the metabolic process is carbohydrate and sufficient amount of oxygen is available. Respiratory quotient (*RQ*) depicts the ratio of the volume of carbon dioxide released to the volume of oxygen consumed by a body tissue of fruit in a given period [1]. The respiratory quotient exhibited minor fluctuations during the initial stage of respiration rate experiments. The respiratory quotient stabilized as the experiment achieved steady state condition. It was observed that, the *RQ* indicated gradual decline at 10 and 15°C temperature in the early stage of experimentation. However, at 20, 25°C and 30°C temperatures, fluctuation observed in *RQ* was very low. These resulted phenomena may be due to the fact that at lower temperature reduces the metabolic activity consequently results in decreasing respiration rate. It was observed that higher temperature enhances the respiration rate and substrate (O_2) is dissolved at a faster rate resulting in production of more CO_2 leading to a faster accumulation of more CO_2 within the closed system and causing an increase in the respiratory quotient even at the early stage of experiment.

At a given temperature condition, RQ was found varying between 1.7 to 0.7 with the time under aerobic condition. *RQ* is less than unity; the O_2 consumption was always higher than the oxidative CO_2 production. This corresponds to some other fresh produce reported by [2, 4, 10, 11, 12]. A change in the respiratory quotient at different temperature was shown in Fig 4.

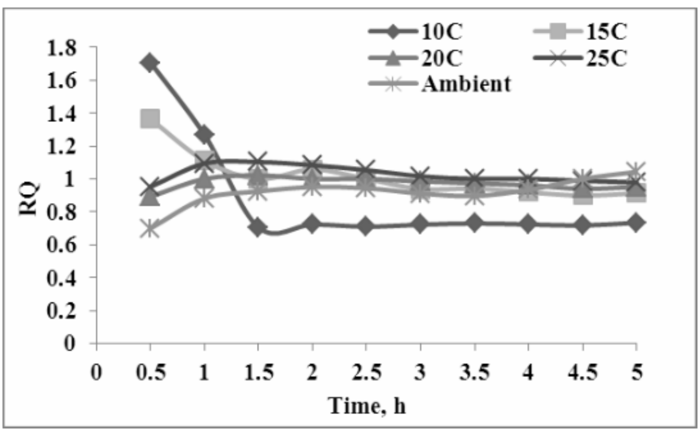


Figure 4. Respiratory quotient (RQ) of Guava at different temperature

CONCLUSIONS

Based on the experiments, it was concluded that the steady-state respiration rates were found to be decreasing with storage time. The respiration rates were also found to be increasing with increasing storage temperature. At all temperatures, the O_2 consumption rate remained higher than the CO_2 evolution rate giving steady-state respiration quotient values between 0.7-1.7 at different temperatures. After 2 hours of storage period, *RQ* was found slightly varying with the time under aerobic condition.

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RESPIRATORNO PONAŠANJE ZRELE SVETLO ZELENE GUAVE (*Psidium guajava L.*) U ZATVORENOM SISTEMU

Ranjeet Singh, Saroj Kumar Giri, Sitaram D. Kulkarni

Centralni institut za poljoprivrednu tehniku, Odsek za preradu poljoprivrednih proizvoda, Nabi Bagh, Bhopal, India

Sažetak: Respiratorno ponašanje je važan aspekt u projektovanju i rukovanju sistemima kao što je kontrolisana i modifikovana atmosfera skladišta koja će produžiti period skladištenja. Stepen respiracije i koeficijent respiracije sveže guave (*Psidium guajava L*. cv. 'Safeda'), ubrane u zreloj svetlo-zelenoj fazi, određeni su u zatvorenom sistemu pri ambijentalnim temperaturama od 5, 10, 15, 20, 25, 30 i 35°C. Stepen respiracije zasnovan na proizvodnji ugljendioksida u aerobnim uslovima opao je za 46% u odnosu na atmosverski vazduh. Potrošnja kiseonika se značajno smanjila na 31% u odnosu na atmosverski vazduh pri temperaturi od 25°C. Dobijeni rezultati upućuju na zaključak da se stepen respiracije guave povećava sa povećanjem temperature, a smanjuje sa produženjem vremena skladištenja. Rezultati ovih istraživanja mogu se primeniti pri projektovanju optimalnih sistema za pakovanje kojima bi se produžio period skladištenja guave.

Ključne reči: *guava, fizičko-hemijske osobine, stepen respiracije, koeficijent respiracije*

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USING THE GLASS FIBRES IN RECYCLING AGRICULTURAL PLASTIC WASTE

Aleksandra Dimitrijević[1*], Carmela Sica[2], Pietro Picuno[2], Giacomo Scarascia Mungnozza[3]

[1] *University of Belgrade, Faculty of Agriculture, Institute of Agricultural Engineering, Belgrade, Serbia*
[2] *University of Basilicata, School of Agricultural Science, Potenza, Italy*
[3] *University of Bari, DISAAT Department, Bari, Italy*

Abstract: The wide-spread presence of plastic material in municipal and agricultural waste has significantly raised the ecology concern in Europe leading to laws and regulations aimed at controlling and reducing waste production, encouraging recycling and reuse as well. Recycling of plastic waste is not new but is a slowly developing process because using recycled materials is limited due to worse properties of recycled plastics if compared to virgin ones. The mechanical recycling of polymers determines a loss of some of their original chemical, physical and mechanical properties due to the role played by some of the degradation factors they were subjected to during their working life. One of the possibilities to improve the properties of plastic products is using diverse fillers like glass or carbon fibres. In this paper, the properties of plastic profiles obtained through mechanical recycling of agricultural plastic material mixed with glass fibres (70% LDPE + 30% glass fibres) were analyzed. The results of the tensile, bending and compression tests here reported show that the mixture of recycled plastic from agricultural application with a suitable different material could be considered as an interesting option for the improvement of the mechanical characteristics

* Corresponding author. E-mail: saskad@agrif.bg.ac.rs

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of these new regenerated products, paving the way to an increase in the sustainability of the agricultural applications.

Key words: *agricultural plastic waste, recycling, plastic bars, glass fibres, mechanical properties.*

INTRODUCTION

The increased use of plastic in agriculture, especially in horticulture and protected cultivation, generates large quantities of agricultural plastic waste that needs to be dealt with. This created a growing concern about the ecology and energy sustainability of the agricultural production [9]. Some data suggest that agriculture, in Europe, is responsible for using 47.5 Mt of plastics in 2007 [2].

In the scientific community, it is common opinion to consider the mechanical recycling as one of the most appropriate systems for the management of plastic waste and by enabling its re-using [1]. Recycling of mixed plastics waste is not new [6]. The first industrial applications in Japan date from 1973. It is well known that it is possible to manufacture rods, stakes, bars, boards, plates, etc. from mixed plastic waste. It is considered an environmental friendly alternative for the plastic waste disposal. Government legislations and regulations in force in different parts of the world similar to the one implemented by the European Union envisage the use of 85% recyclable materials in automotives by 2015 [5], further increase attention towards natural fibres and their composites [11].

So far, the scientific analysis conducted agree that recycled materials are usually characterized by worse mechanical properties compared to those of raw materials. The reasons for this can be found in the fact that agricultural plastic material, especially films, are subjected to many different degradation factors during their application period. On the other hand, the reprocessing phase itself introduces also some stresses in the new material, connected with the different working steps (washing, granulating, pelletizing, extrusion, etc.) that are necessary for the recycling of heterogeneous plastic materials [6]. The mechanical properties of the recycled material may be also influenced by the presence of other factors, such as additives: *e.g.*, the addition of starch to LDPE blends increases the tensile strength and the elongation at break and reduces the Melt Flow Index (MFI) values [10]. Among the functional additives, natural fibres have become a common material for the manufacture of filled plastics as well [8]. It was stated [11] that natural fibres are advantageous in comparison to glass, carbon or similar inorganic fibres in a polymeric matrix due to their low energy cost, positive contribution to global carbon budget, greater deformability, biodegradability, combustibility, ease of recycling, less abrasiveness to processing equipment, lower cost, renewable nature, non-toxicity, high specific strength, etc. On the other side it was stated [4] that adding the glass fibres into the mixture of PET can improve tensile strength and tensile modulus. In their experiment they used PET mixture that contained 10, 20 and 30% of glass fibres. It was also stated [3] that glass fibres are the most used reinforcing materials in structural reinforced thermoplastic since they have high tensile strength and high chemical resistance.

Previously carried eexperimental tests on bars recycled from the post-consumed agricultural plastic films [12] show what mechanical properties of the recycled materials can be expected if additives like calcium carbonate and talc are added in the extrusion process. The experimental determination of their mechanical characteristics enabled the estimation about the possible use of these regenerated plastic profiles in the industrial and/or agricultural sectors, as constructive elements of light structures (*e.g.*, fences, vineyard pergola, little shelters, etc.).

In this paper, the properties of plastic profiles obtained through mechanical recycling of agricultural plastic waste (APW) mixed with glass fibre (70% LDPE + 30% glass fibres) were analyzed. The results of the mechanical tests here reported show that the mixture of recycled plastic from agricultural application could be considered as an interesting option for the improvement of the mechanical characteristics of these new regenerated products.

MATERIAL AND METHOD

Recycled manufactured products were obtained through the mechanical recycling of agricultural plastic films previously used during years 2004-2006 for covering tunnel-greenhouses in a farm located near Lecce (Southern Italy). The plastic recycled bars were produced by an Italian manufacturer for the stockpiling, selection and mechanical recycling of heterogeneous plastic wastes (Alfa Edile, Brindisi). After the collection and transportation to the recycling factory, the plastic films were granulated, melted at about 220 °C and introduced into the extruder to produce 1.5 m long square section bars with the average side equal to 49.4 mm. Ten recycled bars obtained exclusively from regenerated granule of APW were realized in order to compare them with ten recycled bars obtained from 70% of regenerated granules of APW and 30% of glass fibres.

The mechanical properties of these bars were analyzed in the Laboratory for Testing Material of the University of Basilicata (Potenza), by using a computerized universal press machine Galdabini PMA 10 type. The environmental conditions during the trial were: mean room temperature 20 °C, mean relative humidity 70%. From the recycled bars, specimens were obtained according the following dimensions:

- Tensile test: strip-specimen, width 49.4 mm, thickness 5.85 mm, length 190 mm;
- Compression test: cubic-specimen obtained directly by cutting the bars, side = 49.4 mm;
- Bending test: bar-specimen, section 49.4 mm x 49.4 mm, span length 1,100 mm.

Tensile tests were performed, according to the Italian UNI 8422 Standard [14], with a length between vices of 70 mm and a constant deformation speed equal to 10 mm min^{-1}.

Compression tests were performed at a constant deformation speed equal to 10 mm min^{-1}. During these axial tests the Young modulus (E) was calculated based on the tension value at the end of the elastic proportional phase (σ) and the corresponding deformation (ε).

Bending tests were performed at a strain constant speed of 70 mm min^{-1} according with the Italian Standard UNI 7219-73 [13], through the application of a load in the mid-span of a free length of 1.00 m between the supports.

In order to completely assess the strain properties of these new alternative materials, by the tensile tests the values of Poisson coefficient 1/m (obtained through the measurements of the strain in the y cross-direction of application of the load), of shear modulus G (obtained from measured values of E and 1/m) and percentage elongation at yield were obtained too.

RESULTS AND DISCUSSION

Different materials have different properties and therefore behave in different ways under given conditions. If materials are to be used as structural elements, their behavior under load, which is mostly mechanical in nature, must be known. The internal resistance of the material to withstand the applied load is called stress. In that sense the materials recycled from APW and mixture of APW and glass fibres were tested in conditions of tensile, compression and bending stress, in order to define their mechanical properties and to explore the possibilities of using them as structural elements.

In terms of tensile strength (Tab. 1) mixture of APW and glass fibres showed a higher maximal resistance compared to the mixture of the APW. In the area of elastic deformation recycled APW mixture showed higher resistance leading to conclusion that in the terms of tensile stress adding the glass fibres to the APW has lowered the material elasticity.

Table 1. Results for the maximum resistance of the tested recycled materials

Test	*APW*		*APW + glass fibres*	
	σ_e *(N mm^{-2})*	σ_{max} *(N mm^{-2})*	σ_e *(N mm^{-2})*	σ_{max} *(N mm^{-2})*
Tensile	*6.42*	*10.60*	*8.98*	*14.57*
Compression	*5.17*	*20.00*	*9.81*	*19.15*
Bending	*1.90*	*5.45*	*4.62*	*27.22*

By lowering the material resistance adding of glass fibres also caused a significantly lower elongation at break (Fig. 1, Table. 3) causing the new recycled material to be more brittle.

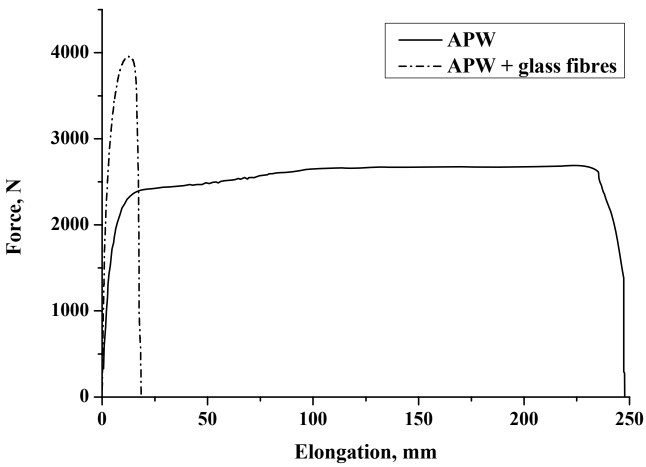

Figure 1. Force-elongation diagram of the preformed tensile tests

Concerning that glass itself is a brittle material this can explain the tensile properties of the recycled mixture of APW and glass fibres in terms of strength and elasticity. A lower quantity of glass fibre could have been probably more suitable for enhancing the mechanical properties of the regenerated profile, without giving it this fragile behavior. Recycled APW showed as more ductile material (Fig. 1) because it can stand large strains before failure.

When compression test is analyzed it can be seen that recycled mixture of the APW and glass fibres showed higher strength at the end of the elastic phase (Tab. 1). On the diagram of the behavior of the recycled materials during the compression test (Fig. 2) it can be seen that the mixture of the APW and glass fibres showed often (three samples over ten) a clear final break, while the APW only material was not finally broken, because the maximum load of the testing equipment (55,000 N) was reached without determining a clear final rupture of the tested specimens. Therefore, the maximum strength of this material was set to more than 22.54 N mm^{-2}.

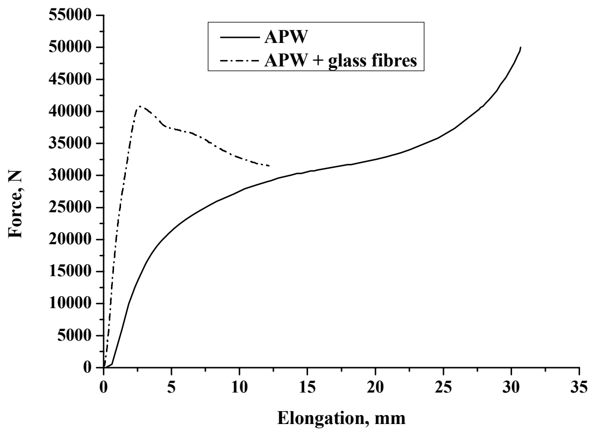

Figure 2. Force-elongation diagram of the compression tests;

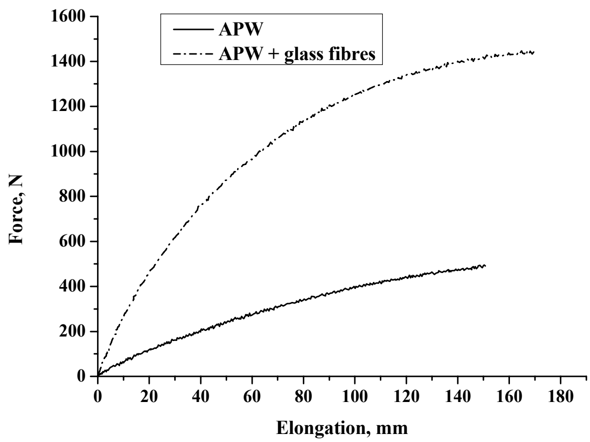

Figure 3. Force-elongation diagram of the preformed bending tests

The bending tests that were performed showed that the recycled mixture of APW and glass fibres has an higher resistance at the end of the elastic phase, compared with the recycled APW material (Tab. 1, Fig. 3). This could be also due to the contribution to the shear resistance given by the glass fibre. During the bending tests, for both of the materials the maximum travel stroke of the testing machine (170 mm) was not enough to cause the break of the specimens, due to high elasticity of these materials.

The analysis of the Young modulus (Tab. 2) showed that recycled mixture of APW and glass fibres has significantly lower flexibility, showing the higher values of Young modulus in all the three categories of test. It can be concluded that adding of 30% glass fibres in the APW could only partially improve the overall material flexibility.

Table 2. Results for the Young modulus of the tested recycled materials

Test	E ($N\ mm^{-2}$)	
	APW	APW + glass fibres
Tensile	114.54	433.64
Compression	119.90	614.05
Bending	305.67	1204.22

The values of the elongation at break pointed out which of the two materials is the most deformable. It can be seen (Tab. 3) that recycled APW only has significantly higher values of the maximum elongation at break.

Table 3. Values for the strain characteristics of the recycled materials during tensile stress

	APW	APW + glass fibres
Maximum elongation at break (%)	394.10	44.07
Poisson coefficient	0.46	0.47
Shear modulus in the elastic phase ($N\ mm^{-2}$)	39.22	147.50

For most metals and many other materials, values for the Poisson coefficient range from 0.25 – 0.35. Tested materials showed finally very similar values that are close to the theoretical upper limit that is 0.5 (rubber comes close to this).

CONCLUSIONS

One possible way of dealing with the growing quantities of agricultural plastic waste is the mechanical recycling, which enables their re-utilization in the agricultural sector through the realization of the cheap and effective products able to improve the sustainability of the agricultural production. Recycling is not a new technology, but it is in constant development since a lot of polymers during the recycling process lose their original mechanical properties leaving the recycled materials with the characteristics that narrow their possibilities of reusing.

Adding some additives into the mixture of agricultural plastic waste before the recycling process was considered by many researchers. In this paper, adding glass fibres into the APW and recycling such material was analyzed in the sense on how does this mixture behave in conditions of tensile, compression and bending stress. Results can serve for the analysis of possible use of the tested materials in some agricultural applications as construction elements or light structures. Recycled APW showed good tensile and compression characteristics. The addition of the glass fibres, in terms of tensile stress, has lowered the APW elasticity, causing the new recycled material to be more brittle. Concerning the compression test, the recycled mixture of the APW with glass fibre showed higher strength at the end of the elastic phase but, at the same time, a lower maximal strength. In conditions of bending stress both materials showed a similar behavior. It can be concluded that the mixture of APW and glass fibres in ratio 70% and 30% causes the new material to be more brittle and sensitive to tensile and compression loads. This makes this material unlikely employable for the realization of structural elements. A different quantity, with a lower percentage, of glass fibre inside the APW mixing, however, could probably usefully contribute to an improvement of the mechanical characteristics of the new regenerated profiles and consequently to their diffusion in the market.

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KORIŠĆENJE STAKLENIH VLAKANA PRI RECIKLAŽI PLASTIČNOG OTPADA IZ POLJOPRIVREDE

Aleksandra Dimitrijević[1], Carmela Sica[2], Pietro Picuno[2], Giacomo Scarascia Mungnozza[3]

[1] Univerzitet u Beogradu, Poljoprivredni fakultet, Institut za poljoprivrednu tehniku, Beograd, Srbija
[2] Univerzitet Bazilikata, Škola poljoprivrednih nauka, Potenca, Italija
[3]Univerzitet u Bariju, DISAAT Institut, Bari, Italija

Sažetak: Intenzivno korišćenje PE i LDPE u poljoprivredi, u poslednjih par decenija, dovelo je u pitanje ekološku održivost poljoprivredne proizvodnje ali je i iniciralo uvođenje i stavljanje na snagu regulatva i zakona kojima se kontroliše i smanjuje generisanje plastičnog otpada uz istovremenu stimulaciju uvođenje procesa reciklaže. Reciklaža kompleksnog plastičnog otpada iz poljoprivrede nije nova tehnologija ali je tehnologija čije su usvajanje i primena veoma spori obzirorom na činjenicu da je njihova reciklaža ograničena mehaničkim karakteristikama recikliranih materijala koje su znatno lošije od karakteristika izvornih materijala. Reciklirani polimeri se karakterišu gubitkom određenih hemijskih, fizičkih i mehaničkih osobina nastalim usled degradabilnih faktora kojima su materijali bili izloženi tokom svog perioda eksploatacije neposredno pred reciklažu. Jedan od načina da se osobine recikliranih materijala poprave je i dodatak određenih aditiva kao što su čestice drveta, stakla, kalcijum-karbonata i dr. U ovom radu su date karakteristike materijala nastalog reciklažom plastike iz poljoprivrede i njenom kombinacijom sa staklenim vlaknima u količini od 30%. Rezultati testova na istezanje, sabijanje i savijanje ukazuju da se dodvanjem adidtiva u vidu staklenih vlakana u plastični otpad iz poljoprivrede, mehaničke karakteristike ovako reciklirane mešavine mogu poboljšati dajući novi materijal koji bi ponovo moga naći svoje mesto u poljoprivrednoj proizvodnji.

Ključne reči*: plastični otpad iz poljoprivrede, reciklaža, plastični profili, staklena vlakna, mehaničke karakteristike*

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MECHANIZED HARVESTING OF LEAFY PARSLEY CROPS IN THE REGION OF SOUTH BANAT

Rade L. Radojević *[1], Dragan V. Petrović[1], Kurt W. Tomantschger[2]
Mirjana R. Radojević[3]

[1] *University of Belgrade, Faculty of Agriculture, Institute of Agricultural Engineering, Belgrade - Zemun, Republic of Serbia*
[2] *Technical University of Graz, Faculty of Technical Mathematics and Technical Physics, Institute of Mathematics A, Graz, Austria*
[3] *Agricultural Middle school "Josif Pančić", Pančevo, Republic of Serbia*

Abstract: So far, many types, styles and sizes of mowing equipment has been developed and introduced in the agricultural practice. Therefore, leaf crops harvesting seems to be easier to mechanize with respect to other cultivars. However, keeping the leaf matter clean and loaded into a dryer without contaminants limits the kind of mechanization that can be used.

In this paper is given a general review of Parsley (*Petroselinum crispum)* crops properties, possible benefits of its applications and basic principles of mechanized growing technology. In addition a simplified agroeconomical calculation of the production costs against possible income from sold vegetables, based on current prices expressed in euros is also provided. This way, the production of Parsley herbs is justified from medical, nutritive, culinary and economical points of view.

Finally, results of testing three harvesters of different design, applied for collecting and preparation of parsley leaves at parcels in the region of south Banat (North Serbia) are presented and analysed. Measurements comprehended following working parameters: harvester velocity, loss of acquired crop and cutting lengths distribution of parsley leafs.

Key words: *mower, leaf harvester, herb, cutting, losses.*

* Corresponding author. E-mail: rrade@agrif.bg.ac.rs

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INTRODUCTION

Parsley (*Petroselinum crispum)*

Parsley (*Petroselinum crispum)(Petroselinum crispum* (Mill.) Nyman ex A.W. Hill) belongs to the family *Apiaceae* and is one of the most popular herbs. Parsley is a biennial herb that is cultivated extensively. However, in some countries, like California, Belgium, France, Germany and Hungary parsley grows as an annual plant. Different parts of parsley herb are used, including its ripened fruits (also known as seeds), leaves as well as the other parts that grow above the ground.

Different parts of Parsley crops have found a number of possible applications, including medicinal, nutrient, as well as culinary.

So far, the leaves, fruits and root of this herb have been used in traditional medicine. However, the parsley is also used in conventional medicine. Fruits (seeds) of parsley are basically applied in the form of a stomachic or carminative. Roots of this crop are used in the form of a diuretic. Compared to the leaves of the plant, the fruits of parsley possess a very strong diuretic action and can be used in place for celery seeds (*Apium graveolens*) for treating arthritis, rheumatism, and gout..

Although people do not consume parsley in enough amounts, this herb is an excellent natural resource of pro-vitamin A (carotene), vitamin B1, vitamin B2, vitamin C, iron as well as other valuable minerals [6]. For instance, the fresh leaves of parsley are extremely nourishing and may be deemed to be a natural vitamin as well as mineral supplement in their individual capacity.

Parsley has been also used for culinary purposes. Today this herb is extensively cultivated throughout the world in the form of a nourishing herb. The leaves of parsley are harvested anytime between spring and autumn - the growing season of the plant [9].

Parsley is propagated by its seeds, which germinate extremely sluggishly [1]. Parsley grows best in extremely rich and well-drained soil and can endure pH range between 4.9 and 8.2. In the first year of their growth, parsley plants have a solitary leaf rosette [5]. If the Parsley herbs are grown primarily in order to produce fruits (seeds), the plants should be kept in the ground till their second growth season, when they actually bloom and produce seeds [8] [10].

Recent harvesting solutions for leafy parsley

The mechanization of leafy herbs and medicinal plants production is less developed with respect to production of other plant species in horticulture. The harvest is a particular problem, even for those plants that are harvested by machines designed for other plant species. A typical example is the leafy plants such as peppermint, lemon balm, thyme, sage, nettles, marjoram, parsley and other leafy vegetable plants.

Depending on the crop quality, multiple harvests of parsley are possible either by machine or manually. Under conditions of dry land farming, harvest could be performed three times per harvesting season. If irrigation is proprely applied, even four harvests per season are possible. For multiple harvests, Parsley plants should be cut at least 3 cm above the crown. In general, machine-harvested fields are mechanically chipped in a way to provide cutting plane in the range between 2.5cm and 7.5 cm above the crown, and after cutting transported to dehydrators.

Cutting, combing, stripping, vibration and threshing are different functions used for the detachment of the very wide range of aerial parts found in the diverse commodities to be harvested.

Cutting action is applied mainly to the leafy parsley, and any other green or similar plant parts. Each of these products needs multiple harvests for maximum yield specified to be sold at fresh market. In all cases, they have to be cleanly removed and handled softly for minimum leaf loss. Cutting is the most effective removal method, but it is also used in combination with other harvesting systems

Figure 1. Ploeger - MKC 4TR parsley stripping unit

Among the others, the Ploeger MKC 4TR power unit [4] represents a possible contemporary solution in the area of parsley harvesting, Fig. 1. It possess 6 meters wide parsley stripping element, equipped with cutting units directly after stripping device. The stripped parsley is conveyed into the container while the cut stems are transported onto the track path to avoid diseases and to create a uniform second grow of the crop. The stripping unit is delivered with a special platform, which facilitates transport of the stripping unit from one field to the other. This platform can be easily lifted by the hook lift system on the backside of the MKC 4TR power unit.

Justifiability of Parsley (*Petroselinum crispum)* production

Republic of Serbia does not possess the statistic's records on the parcel areas under the parsley. However, estimated value is about 2700-3000 *ha* [2]. In addition, varieties selection of parsley cultivar is very poor.

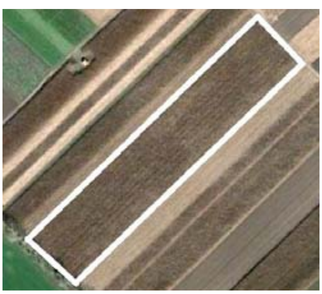
Although production of leafy parsley is not widespread in Serbia, results of simplified calculations presented in Tab. 1, [3] justifiy the investements neccessary for production of crops of this kind.

Table 1. Calculation of parsley leaf production

Materials and operations	Measurement unit	1 ha	Price (Euro)	Costs (Euro/ha)
1. Material				
Seeds of parsley	kg	10	30,00	300,00
Livestock manure	t	30	20,00	600,00
Water for irrigation	l			100,00
TOTAL /1/				1000,00
2. Work of tractor				
Plowing at 25 cm	working day	0,6		
Discing	working day	0,3		
Distribution of manure	working day	1,0		
Plowing of manure	working day	0,5		
Sowing	working day	0,1		
Interrow cultivation	working day	1,0		
Mowing the leaves of parsley	working day	1,0		
Other works	working day	1,0		
TOTAL /2/		5,5	90,00	495,00
3. Manual work				
Distribution of manure	working day	12	15,00	180,00
Sowing	working day	2	15,00	30,00
Loading / unloading	working day	5	15,00	75,00
Hoeing, weeding	working day	20	15,00	300,00
Collecting raw materials from field	working day	10	15,00	150,00
TOTAL /3/				735,00
TOTAL COSTS /1+2+3/				2230,00

MATERIALS AND METHODS

This paper presents results of testing three systems, commonly used in Serbia for mechanized harvesting of parsley leaves. The experiments were conducted during the second decade of the June 2012 in the region of the South Banat in north-east Serbia. Rectangular experimental plot is placed on flat terrain between the villages Kovin and Bavanište, at altitude 78 *m*. The position of experimental parcel, which photograph is given in Figure 2, is spatially defined by its GPS coordinates: 44°48’ N and 20°53’ E.



A

b

Figure 2. Experimental plot: a) plan view and b) crop

Cultivar of leafy parsley “*Domaći lišćar*” was growed on the experimental plot, using the following technological operations:

1. primary tillage;
2. presowing preparation (as for alfalfa);
3. sowing, performed in late February and early March, at a depth of 2 cm, and at 25 cm row spacing;
4. crop protection:
   - spraying of herbicides (late march);
   - spraying against of sorghum (early may);
   - fertilization after emergence and
   - leaf harvesting (starts in mid–June).

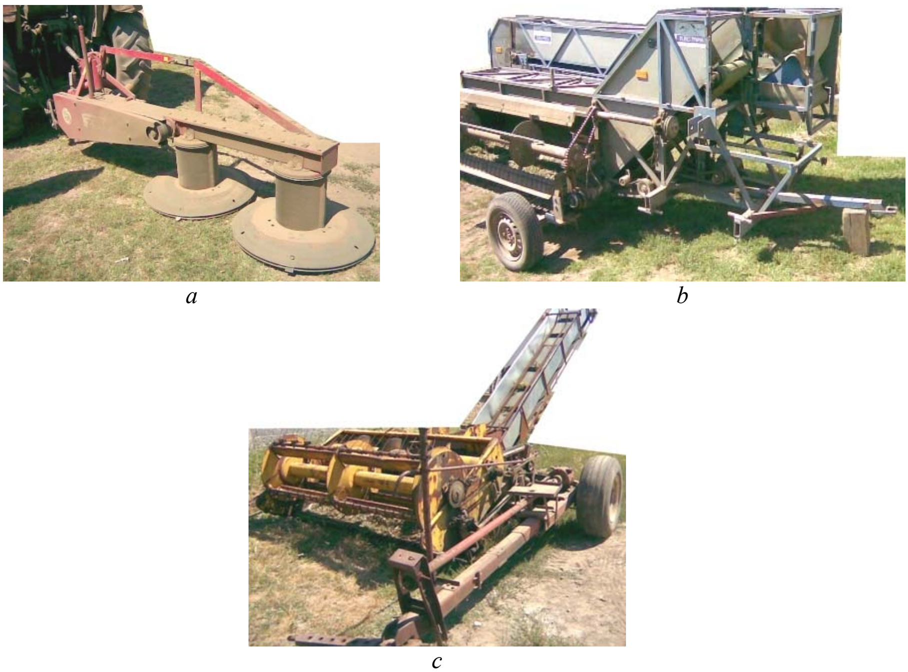


Figure 3. Tested machines: a) mower "SIP ROTO 165",
b) harvester-mower "Euro Prima NB 2004" and c) silage harvester "Pobeda KS-69/A"

The leaf humidity was 70.8-78.3 % during the harvesting process, which involved cutting plants, collection and transport to the drier [7]. Parsley leaves were mowed by tractor MTZ 820 aggregated by three different harvester systems:

- mounted (carried) rotary drum mower, Mower "SIP ROTO 165"
- mounted (carried) harvester-mower for leafy vegetables "Euro Prima NB 2004";
- adapted trailed forage harvester, Silage harvester "Pobeda KS-69/A".

Machines used are presented in Figure 3, while their technical characteristics are given in Table 2.

Table 2. The characteristics of harvesting machines

TECHNICAL DATA	Mower SIP ROTO 165	Harvester-mower Euro Prima NB 2004	Silage harvester Pobeda KS-69/A
Hitch	Mounted at 3 points	Mounted at 3 points	Trailed at single point
Cutting device	Rotational knives on drums	With double cut scythe	Conventional, with single cut
Working width (mm)	1650	1800	2200
Weight (kg)	392	1100	1200
Transport width (mm)	1340	2000	2200
Transport length (mm)	2850	5300	5200
Maximal height (mm)	1110	1900	3500
Max. no of P.T.O. shaft rotations (min^{-1})	540	540	540
Required tractor power (kW)	22	60	48
Working speed ($km\ h^{-1}$)	12-15	2-5	4-7
Mowing capacity ($ha\ h^{-1}$)	2	0,5	1

Parameters of the herb samples were determined by manual separation of samples acquired at the operational harvesting length of 1m. Forward speeds of all three harvesters were recorded during harvesting, as well as the loss.

RESULTS AND DISCUSSION

Experimental harvesting of parsley leaves was performed by three harvester systems:

1. Harvesting of Parsley leafs by the first system (mounted rotary drum mower "SIP ROTO 165") assumed cutting the plants with rotary blades and disposing the swath on land. In the next phase, cutted mass was collected manually by forks, and put into the trailer. Consequently, this system was the most unfavorable with respect to other two tested systems. Mass losses reached the highest values, because the product leaves after cutting fell down to the ground surface and manually collecting led to occurrence of non picked-up mass on the soil (ground) surface. This, except major losses, implies higher costs of manual workforce, while reducing the quality of the collected mass that comes into contact with the surface of the plot and thus polluting.
2. The second system, mounted harvester-mower "Euro Prima NB 2004", cuts leaves mass with double cuts, reducing the possibility of obstruction on the cutter bar. Finally, conveyor belt, which is built in the trailer and aggregated on the back side of the combine, inserts the cut off the mass in the trailer. Main disadvantage of this design is related to the fact that there is no ability to change the speed of conveyor. Consequently, in the case of higher mass density, an obstruction of conveyor belt may occure.

3. The third system for collecting leaf Parsley, adapted trailed forage harvester "Pobeda KS-69/A", arised after modifying the basic construction of forage harvester. There were two kinds of modifications, done in order to use the machine in parsley harvesting: (a) transport rollers (which deliver mown mass up to the cutter), cutter and conveying tube were removed; (b) the elevator, belt conveyor with laths (which delivers mown mass to the trailer) were added. This way, the adapted machine cuts mass by classical oscillatory cutting bar with a movable operating body. The belt conveyor, aggregated at the back side of the combine, transports the cut off mass and inserts it in the trailer. Under various operating conditions, the inmproved design of this harvester showed stable work, exposing the least disparities of operational characteristics from the optimal values and had a minimum of malfunction when compared to other two tested machines.

Average operational parameters of harvesting machines, determined under experimental cutting the Parsley leaves, are presented in the Table 3.

Table 3. Average operational parameters of harvesting machines

Parameter	*Type of harvesting machine*		
	Mounted rotary drum mower "SIP ROTO 165"	*Mounted harvester for leafy vegetables "Euro Prima NB 2004"*	*Adapted trailed forage harvester "Pobeda KS-69A"*
Constructive working width (m)	*1.65*	*1.80*	*2.20*
Realized working width (m)	*1.44*	*1.58*	*2.02*
Working speed (km h^{-1})	*11.34*	*1.16*	*2.37*
Cutting height (cm)	*8.31*	*5.53*	*7.28*
Losses (%)	*18.41*	*5.69*	*3.16*

Process of harvesting the Parsley leaves should facilitate further processing and drying of the cutted mass. In the final stage of processing the stems with leaves, complete mass is dried and leaves are separated from the stalk after drying. Therefore, the heat energy is consumed for drying stalks, which has no practical value.

Low stem cutting height, below 6 cm, characterised the second system (mower "Euro Prima NB 2004"with two knives), which is not recommended for the parsley. Rotary drum mower "SIP ROTO 165" generated a greater amount of cutting mass with respect to other tested machines, due to higher operating speeds. This system achieved the best cutting height in comparison to other two tested mowers, because of the better maintaining the configured cutting height.

Besides the amount of processed cutting mass, realized mass losses of mower at work is a key parameter to evaluate the quality of machine. Classic mower "Pobeda KS-69A" has achieved the lowest total mass loss (3.16 % of the average yield of green mass). The medium level of mass loss was evidenced when the harvester with two mower blades "Euro Prima NB 2004" was tested 5.69% in average. Rotary mower have achieved greater total losses with an average loss of 18.41 %. Rotary drum mower "SIP ROTO 165" achieved significantly greater losses with respect to other two harvesters. This was not caused by mowing, but was a direct consequence of utilization of other hand operations that decreased the overall efficiency of harvesting process (mowing and manual collecting).

Machine with classic mower ("Pobeda KS-69A") achieved a satisfactory height level of stem cutting, but the operating speed was limited due to design of cutting device. This property, in addition to smaller working width, affects (decreases) the surface productivity, which was about 0.48 ha h^{-1} in average. Mower with two blades "Euro Prima NB 2004" achieved productivity of about 0.18 ha h^{-1}, while the drum rotary mower "SIP ROTO 165"achieved 1.63 ha h^{-1}.

CONCLUSIONS

For production conditions in Serbia, examined technical solutions for the harvesting of leafy parsley did not give satisfactory results. The first tested system, which demands manual (hand) operations (related to crop collecting) is especially inefficient and its application should be prevented in the future. Therefore, hit can be concluded that harvesting process must be completely mechanised and automated.

The future farm will be a multifunctional agricultural production unit, employing considerable technology and technological skills. The quality of the final product mostly depends on the harvesting method. Consequently, farm managers must persevere in continual extensive evaluation of existing harvester designs and in exploring the new possible solutions for machine's design.

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MEHANIZOVANA BERBA PERŠUNA U REGIONU JUŽNOG BANATA

Rade L. Radojević[1], Dragan V. Petrović[1], Kurt W. Tomantschger[2] Mirjana R. Radojević[3]

[1] *Univerzitet u Beogradu, Poljoprivredni fakultet, Institut za poljoprivrednu tehniku, Beograd - Zemun, Srbija*
[2] *Tehnički Univerzitet Grac, Fakultet za tehničku matematiku i tehničku fiziku, Institut za matematiku A, Grac, Austrija*
[3] *Srednja poljoprivredna škola "Josif Pančić", Pančevo, Srbija*

Sažetak: Do sada je razvijen i uveden u poljoprivrednu proizvodnju veliki broj tipova i konstrukcija mašina za košenje. Stoga se čini da je mehanizovanje žetve lisnatih useva lakše u poređenju sa ostalim kulturama. Ipak, očuvanje čistoće lisnatih useva i njihov utovar u sušare bez neželjenih kontaminanata ograničava vrstu opreme koja se može koristiti. U radu je prikazan opšti pregled opreme i postupaka za mehanizovano ubiranje peršuna (*Petroselinum crispum*). Na osnovu uprošćene ekonomske analize, zasnovane na tekućim cenama u Srbiji izraženim u evrima, potvrđena je opravdanost uzgoja ove poljoprivredne kulture sa ekonomske tačke gledišta. Konačno, prikazani su i analizirani rezultati uporednog testiranja tri kombajna različite kontrukcije, primenjene za sakupljanje i pripremu lišća peršuna na parcelama u regionu južnog Banata (severna Srbija). Merenjem su obuhvaćeni: brzina kombajna, gubici sakupljenog useva i raspodela dužina isečenih frakcija peršuna.

Ključne reči: *kosačica, kombajn za lišće, biljka, sečenje, gubici*

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Institut za poljoprivrednu tehniku
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DISCRETE ELEMENT METHOD (DEM) MODELLING OF COHESIVE SOIL-TOOL INTERACTION

Krisztián Kotrocz*, Kornél Tamás, György Kerényi

Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Machine and Industrial Product Design, Hungary

Abstract: The soil-tool interaction is an important role in modern agricultural researches. In this paper a cultivation tine tool was simulated in operation with the working speed of 1 m s^{-1} and working depth of 20 cm using discrete element method (DEM). The parallel bond model was used to demonstrate the cohesive behaviour of the soil. Three analyses were created with different material properties and during the simulations the draft force was measured to compare it with soil bin tests' results. After the soil-tool analyses three tri-axial tests were performed with the same material properties to measure the cohesion and the internal friction angle.

Key words: *discrete element, DEM, parallel bond, cohesive soil, tool*

INTRODUCTION

Many articles have been published in recent decades to improve the design of the tillage tools. There are some analytical and numerical methods available to investigate the soil-tool interaction. The first analytical theories were developed in the 1970s and summarised by McKyes [1]. This method gives very accurate results but only with simple blades. If the shape of the tool is complex there will be an error in the calculations so numerical analyses are necessary to describe the dynamic behaviour of the soil. Finite Element Method (FEM) has been used since the early 1990s to model the soil-tool interaction [2-4]. In FEM models the soil is modelled as a homogeneous

* Corresponding author. E-mail: kotrocz.krisztian@gt3.bme.hu

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isotropic material. While real soils consist of individual particles which slide and roll on each other during the cultivation process, their displacements are discontinuous so this material can not be modelled by FEM correctly.

There is another type of the numerical simulations the so-called Discrete Element Method (DEM) which was developed by Cundall and Strack [5]. In DEM each particle has its own displacements depending on the contacts with walls or other balls. Contact forces can be calculated from the material parameters (e.g.: stiffness) and the overlap of two elements. According to Newton's second law the motion of the particles can be determined in every calculation cycle. Therefore this method is the most suitable to model the soil mechanical behaviour, so many studies have been created in recent years [6-8].

In this work we created a 3D model to simulate the process of the cultivation tine tool and to calculate the average draft force. Different material properties were added to calibrate a model and all three simulated material was examined by tri-axial tests.

MATERIAL AND METHODS

To calibrate the material properties of the DEM model real in-situ or soil bin measurements' results are necessary. In the laboratory of the Hungarian Institute of Agricultural Engineering of Gödöllő some soil bin tests were performed to determine the draft force of the tillage tool with different draft speeds in the winter of 2009 [9]. First step was to create this tool's geometry in the 3D CAD system with the specific parameters. The tool has a sweep angle of $2\gamma = 57°$, a rake angle of $\beta = 20°$ and a width of 310 mm, which correspond with the data in [10].

In the DEM software it is possible to import 3D CAD geometry as walls, but only *.stl file format is supported. Therefore the simplified geometry of the tine tool needs to be converted to *.stl format with a CAD software. This STL-mesh is shown in Figure 1.

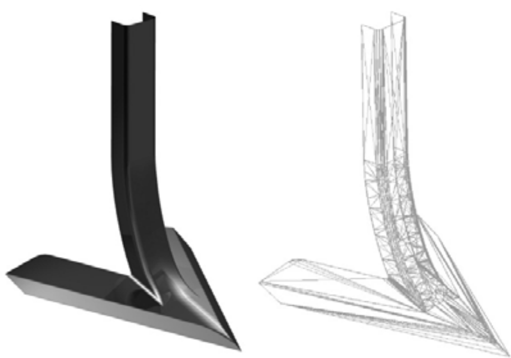

Figure 1. The 3D CAD geometry and the STL-mesh of the tine tool

To model the soil mass a box was created with the dimensions and mechanical parameters shown in Table 1. Within this box 5000 pieces of discrete elements were generated with the radius range from 2 to 5 mm. To fill the box and reach the porosity of

0.4, the radius of the balls were multiplied then many calculation cycles were carried out to approach the mechanical equilibrium state (see in Figure 2). This can be determined by monitoring the velocity of the balls or the mean unbalanced force during the simulation. In Figure 3 the velocity of a selected ball with identical number (ID) 1309 is shown. After 200 000 steps this value reduced to almost zero, so the system reached the equilibrium state.

Table 1. The geometrical parameters of the simulations

Geometrical parameters		
Walls (box and the shape of the tool)		
Length of the box	*1000*	*mm*
Height of the box	*700*	*mm*
Width of the box	*600*	*mm*
Working depth of the tool	*200*	*mm*
Balls		
Number of balls	*5000*	*-*
Radius	*12…30*	*mm*

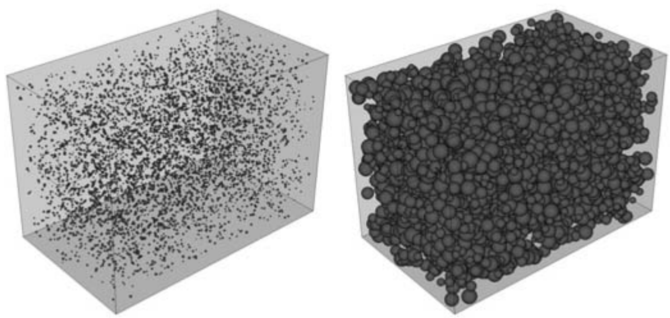

Figure 2. The 3D DEM model before (left) and after (right) increasing the ball's radii

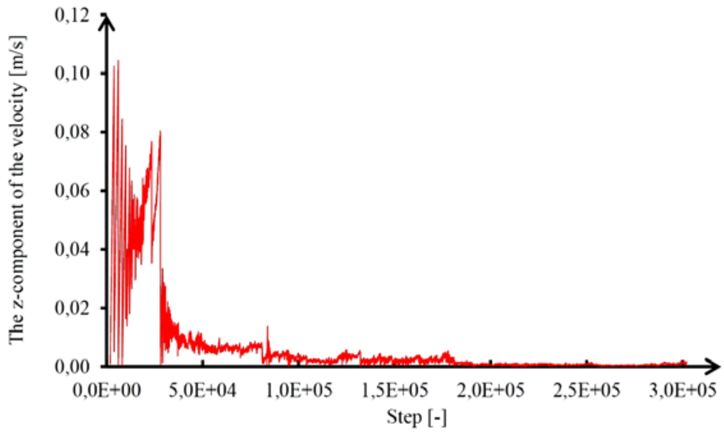

Figure 3. The velocity's z-component of the ball ID 1309

After importing the tool's geometry the mechanical parameters of the soil must be added to the model. The discrete elements can not be deformed, therefore it is important to define the contact properties of the balls correctly. To model the cohesive behaviour of the soil the so-called Parallel Bonds were added. This type of contact was developed by Potyondy and Cundall [11] and can be envisioned as a set of elastic springs with stiffness's in normal and shear direction. These springs act in parallel with the normal and shear direction of the contact as shown in the right side of Figure 4. Relative motion of the two contacting elements (displacement and rotation) causes a contact force and a moment to develop within the bond, respectively. To define the contact stiffness-, strength parameters and the so-called parallel bond radius must be added to the model. Over and above viscous damping and friction were defined between the balls as well as the mechanical parameters of the walls (e.g.: normal- and shear stiffness's, velocity etc.). These are listed in Table 2, separately for each of the three analyses (see Analysis 1, 2 and 3). All of the three calculations were completed with the time step of dt = 1×10E-6 sec.

Table 2. The mechanical parameters of the simulations

Mechanical parameters			
Walls (box and the shape of the tool)			
Normal stiffness		2×10^{30}	*N/m*
Shear stiffness		1×10^{30}	*N/m*
Speed of the tool (Draft speed)		*1*	*m/s*
Balls			
Friction coefficient		*0.5*	-
Density		*1850*	kg/m^3
Viscous damping coefficient		*0.7*	-
Parallel Bond normal stiffness	*Analysis 1*	4×10^7	*Pa/m*
Parallel Bond shear stiffness		2×10^7	*Pa/m*
Parallel Bond normal strength		2×10^5	*N/m*
Parallel Bond shear strength		1×10^5	*N/m*
Parallel Bond radius		*1*	-
Parallel Bond normal stiffness	*Analysis 2*	4×10^6	*Pa/m*
Parallel Bond shear stiffness		2×10^6	*Pa/m*
Parallel Bond normal strength		2×10^4	*N/m*
Parallel Bond shear strength		1×10^4	*N/m*
Parallel Bond radius		*1*	-
Parallel Bond normal stiffness	*Analysis 3*	4×10^5	*Pa/m*
Parallel Bond shear stiffness		2×10^5	*Pa/m*
Parallel Bond normal strength		2×10^3	*N/m*
Parallel Bond shear strength		1×10^3	*N/m*
Parallel Bond radius		*1*	-

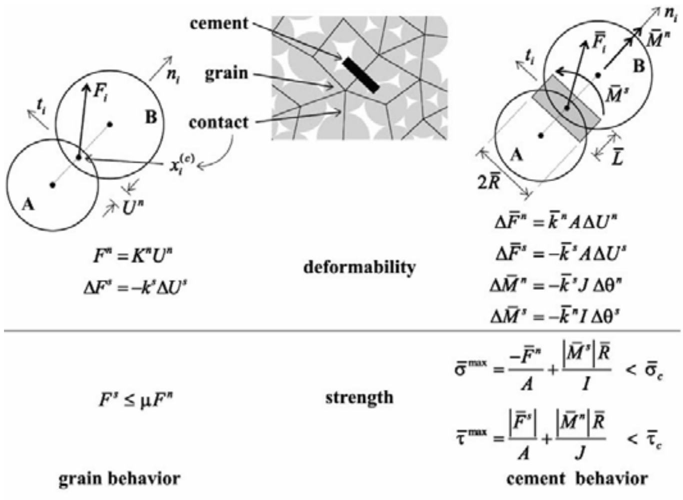

Figure 4. The Parallel Bond Model [11]

Parallel with these analyses three tri-axial tests were performed with DEM to measure the cohesion and the internal friction angle of the three types of soil which are described above. The theoretical background of the simulations is detailed in [1]. From the results of the tests (the first and third principal stresses) the Mohr-cycles and the Coulomb-lines can be drawn. The angle of the Coulomb-lines and the horizontal axis defines the internal friction angle, the intersection with vertical axis defines the cohesion. The confining stresses were 28 kPa, 34 kPa, 48 kPa and 54 kPa, respectively.

RESULTS AND DISCUSSION

The results of the three simulations are shown in Figure 5…9. First the effect of the tine tool was analysed. During the operation the tool forces the particles to move, so the displacements of the elements are much greater in front of- and above the cultivation tool than in the bottom of the box (see in the right side of Figure 6 where the magnitude of the displacement-vectors is proportional with the size of the arrows.).

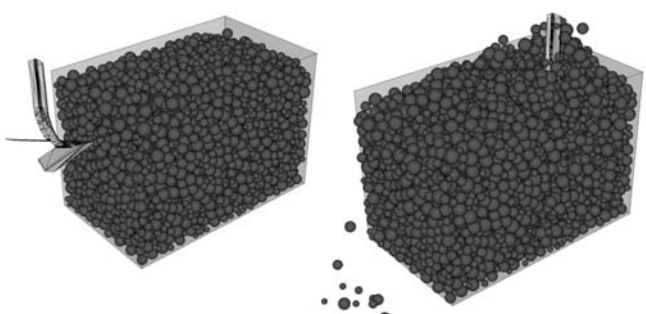

Figure 5. Screenshots from the start (left) and the end (right) of the third analysis

Near the tool the parallel bonds disappeared because the contact forces reached their maximum values which are defined with the contact stiffness's parameters. This result can be seen in the left side of Figure 6 where the parallel bonds were shown as black lines. But in Figure 5 there are some particles above and ahead of the tool which move together because of the remaining parallel bonds. This represents the cohesion between the elements so the simulations seem to be acceptable.

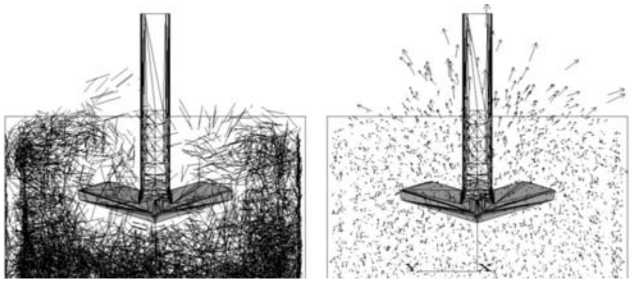

Figure 6. The Parallel Bonds (left) and the elements' displacements (right) in the third analysis

During all of the three analyses the draft force was measured, the values are shown in Figures 7-9. In the first steps the tine tool does not reach the soil-model completely, so only the values from the step nr. 100 000 were considered in the evaluation (these are represented as red, black and blue in the figures, respectively). The nature of the results is very similar to the results of the soil-bin tests [9], particularly in the second and third analysis. The values of the draft forces scatter widely which is corresponding with the real measurements' results. From this data the step-based average values were calculated. The average draft force of the first and the second simulation are approximately equal to the soil-bin test value (F=1170…1220 N) [9]. In the third analysis the mechanical parameters of the contacts are too small therefore we got a small value as draft force. (The values of the average draft forces are shown in the title of each figure.)

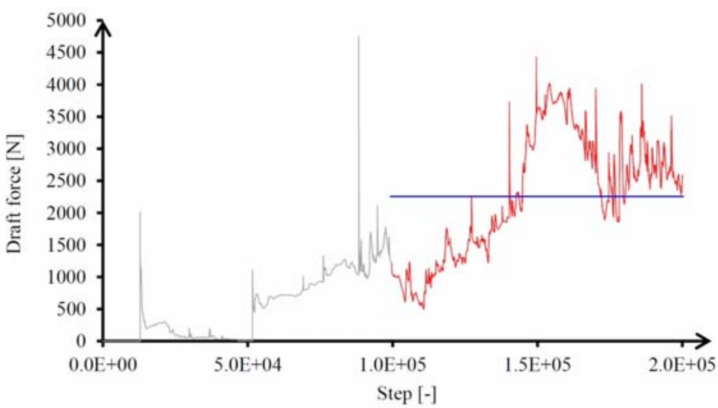

Figure 7. The result of the first analysis, draft force as the function of step (average value is 2257.3 N shown as blue)

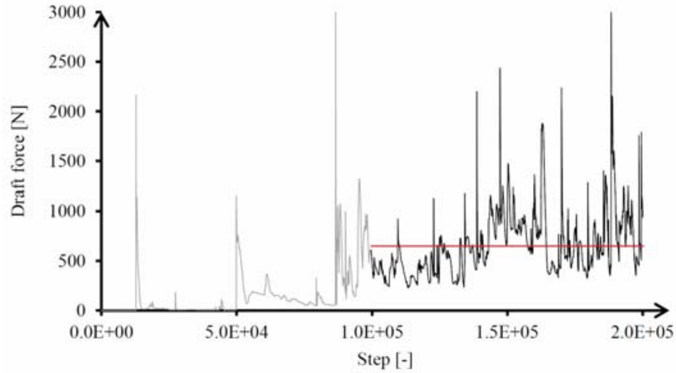

Figure 8. The result of the second analysis, draft force as the function of step (average value is 654.2 N shown as red)

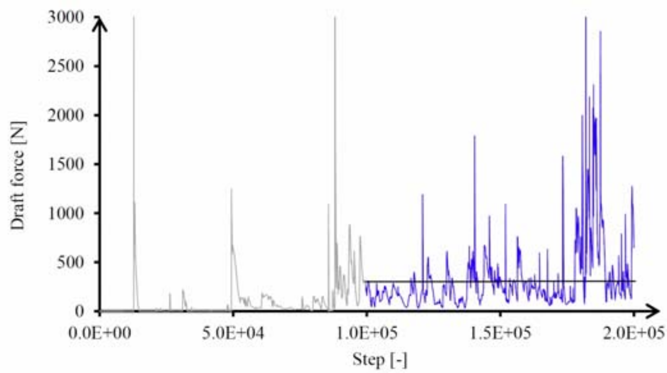

Figure 9. The result of the third analysis, draft force as the function of step (average value is 310.8 N shown as black)

The results of the tri-axial test are shown in Figure 10-12. In the diagrams the negative y-axis and the x-axis define the axial stress as the function of axial strain. In turn the positive y-axis and the x-axis define the shear stress as a function of axial stress. In this diagram the Mohr-cycles can be drawn and the internal friction angle and the cohesion can be calculated [1]. Table 3 contains exact values of these parameters.

The first soil has high cohesion (70.8 kPa) which causes the high values of the draft forces in the first simulation. But in the second and the third analysis the cohesion is about zero which means that we can not get any parallel bonds between the elements at the end of the second and the third soil-tool simulation. In Figure 5 there are some parallel bonds above the tine tool, so probably the cohesion will not be equal to zero, but it has a very small value. Therefore it is possible that some particles move together at the end of the simulations. In these analyses the parallel bond strengths are very small compared to the stiffness's, so increasing the value of the strength will cause that we will get a higher cohesion and higher draft force as results.

The internal friction angles are close to the real values (15…35°) [1].

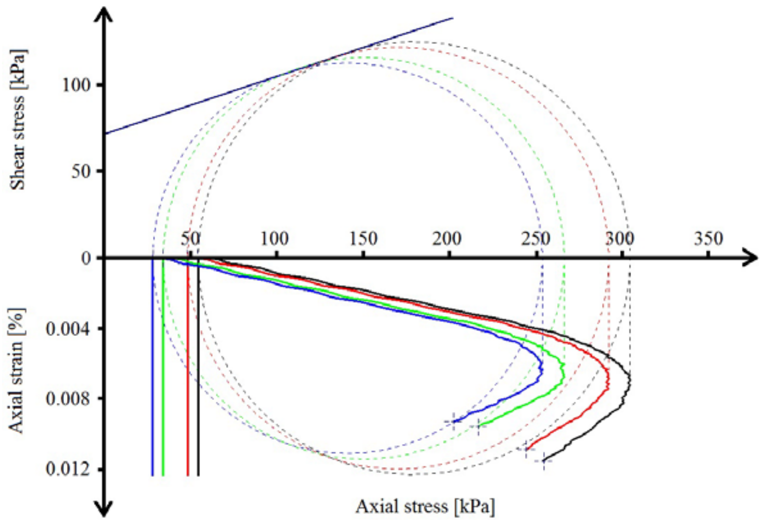

Figure 10. The result of the first tri-axial analysis

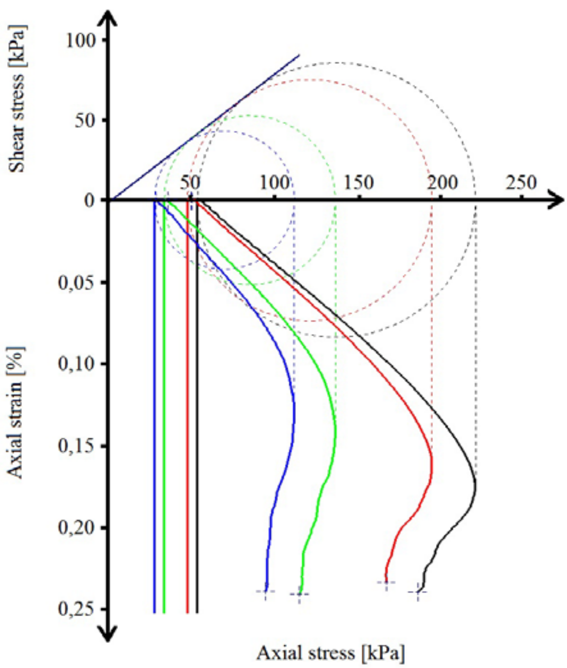

Figure 11. The result of the second tri-axial analysis

Table 3. The results of the tri-axial tests

	Cohesion		Internal friction angle	
Analysis 1	70,8	kPa	18,4	°
Analysis 2	0	kPa	38,1	°
Analysis 3	0	kPa	37,8	°

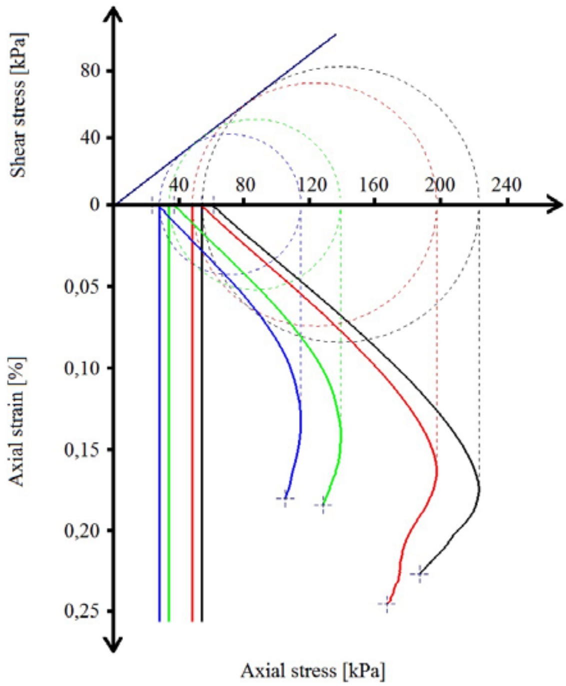

Figure 12. The result of the third tri-axial analysis

CONCLUSIONS

We created a 3D discrete element model to simulate the soil-tool interaction during the operation. Three analyses were carried out, each with the working speed of v=1 m/s and working depth of 20 cm. The soil's cohesive behaviour was modelled by parallel bonds. The displacements of the particles are appropriate and the soil's loosening and cutting process can be well simulated with the developed model even with complex tool shapes. Therefore these simulations are suitable to substitute the expensive soil bin or in-situ measurements.

To verify the results real soil bin tests and tri-axial DEM analyses were performed. Comparing to the soil bin results we can determine that the tendency of the draft forces is the same. The values scatter widely, but with well calibrated material parameters the magnitude of the average draft force is acceptable.

In the tri-axial tests we got the same results. The first soil has high cohesion, therefore with these material parameters soils with high moisture can be simulated. In the second and third tri-axial analysis the cohesion is about zero so sandy soils can be modelled correctly. The values of the internal friction angle are corresponding too with real measurements.

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MODELIRANJE KOHEZIVNE INTERAKCIJE IZMEĐU ZEMLJIŠTA I ORUĐA METODOM DISKRETNIH ELEMENATA

Krisztián Kotrocz, Kornél Tamás, György Kerényi

Univerzitet tehnologije i ekonomije u Budimpešti, Mašinski fakultet, Institut za mašine i industrijske proizvode, Mađarska

Sažetak: Interakcija između zemljišta i oruđa ima važnu ulogu u savremenim poljoprivrednim istraživanjima. U ovom radu je prikazana simulacija rada noža radnog organa za obradu zemljišta čija je radna brzina 1 m s^{-1} a radna dubina 20 cm korišćenjem modeliranja metodom diskretnih elemenata (DEM). Korišten je paralelan model da bi se pokazalo kohezivno ponašanje zemljišta. Napravljene su tri analize sa različitim materijalnim osobinama i tokom simulacije merena je vučna sila da bi se uporedila sa rezultatima testova u zemljišnom bazenu. Posle analize zemljište – oruđe, izvedena su tri tro-aksijalna testa sa istim osobinama materijala u cilju merenja kohezije i ugla unutrašnjeg trenja.

Ključne reči: *diskretni elementi, DEM, paralelni spoj, kohezija zemljišta, oruđe*

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THE ROLE OF THE STRATEGY IN THE INNOVATION ABILITY OF THE HUNGARIAN AGRICULTURAL MACHINERY MANUFACTURERS

Árpád Bak*[1], Zoltán Szira[2]

[1]Szent István University, Faculty of Mechanical Engineering, Institute of Engineering Management, Gödöllő, Hungary
[2]Szent István University, Faculty of Economics and Social Sciences, Institute of Public Administration and Business Law, Gödöllő, Hungary

Abstract: The current production of the Hungarian agricultural machinery manufacturing sector, which used to see better days, lags behind the production of the previous years to a great extent. The organisational structure of the Hungarian agricultural machinery production has totally been transformed, primarily regarding its ownership structure. The general problem of this sector is that they can only spend slight amounts on development an innovation relative to foreign-owned concerns. As a consequence, loss of market is not surprising as a bit more than one-quarter (26-27 percent) of the current total domestic market turnover derives from domestic manufacturers. The extent of market loss and the general situation of the national agricultural machinery manufacturers justify that the present of this sector must be dealt with by searching the ways-out of the crisis and make steps to develop.

The conclusions of our paper are based on the examination results of questionnaires and in-depth interviews that were carried out at 58 Hungarian agricultural machinery manufacturing companies. The characteristic features of the companies that were involved in the examination reflect the situation of the entire sector in Hungary properly. According to our experience and sources, the Hungarian conditions are also applicable and typical of the agricultural machinery production of the other ex-Socialist countries.

In our paper first of all the method of the empirical research is presented where the structure of the questionnaire used in the research and the process of data recording and processing are shown in details. In our present study some of our results together with

* E-mail: bak.arpad@gek.szie.hu

those based on univariate descriptive statistics are published. Besides the brand-new or highly developed products and technological (procedure) innovations, furthermore, some of the indicators of the strategy of the companies are also presented.

Key words: innovation, agro-technical development, key-factors of innovations,

INTRODUCTION

It is an empirical fact that besides the financial constraint, structural troubles also prevent the national technical innovations from being successfully developed.

In Hungary the total expenditure on research and development reached 299.5 billion HUF in 2009, which was 1.14 percent of GDP (GERD indicator). It means a 12.3 percent growth relative to the previous year at current prices [4].

The share of the state of the GDP-related R&D expenditure is 0.42 percent of the total sum (state-owned research institutes and those in higher education altogether) while the expenditure of the business sector amounts to 0.58 percent of GDP. This proportion has been improving relative to the previous ones or, rather, approaches the international practice. However, approximately 60 percent of the R&D expenditure of the national business sector is realised by exclusively foreign-owned enterprises or those which are mostly in foreign hand [5]. In most of the developed countries the national companies spend more of their revenues on R&D expenditure than the foreign-owned ones.

The high-level concentration of corporate R&D can also be observed: almost half of the expenditure derives from 17 big companies. The share of those employing fewer than 20 employees is only 12.6 percent.

Unfortunately, in the sector of the national small-and medium-sized enterprises not only research and development but also the number of licenses and know-how purchase is slight, so the demand (pull) side of innovation is weak under the present system of conditions [7].

- 72-74 percent of the segment is inactive regarding innovation or simply struggle to survive.
- 22-23 percent belongs to those catching-up, i.e. they show some initiatives in innovation that could prevail in the standard of their products and services by means of technological transfer, information and advisory institutions.
- Only 3-6 percent of companies make up the group of promising innovative companies [6].

According to our experience the above-mentioned facts can also hold true for agri-technical innovations more or less. Before the change of the regime only 27 agricultural machinery plants operated mostly "embedded" in the system of the national "agri-business" [2]. Due to this fact (among others), 60 percent of the requirements for agricultural machinery in the country were covered by these plants at a more advanced standard than the average of the former Comecon countries. During the past 15-20 years the organisational structure of the Hungarian agricultural machinery production has totally been transformed. Generally, the machine manufacturers operating as small-or medium-sized enterprises appear on the market with "separate" products usually not developed by themselves. Consequently, they are not price-setters, rather price takers.

The product line of the companies that are successful in the international competition primarily consists of mass-produced and highly automated products. The national agricultural machinery manufacturers-partly due to their size- are not able to mass-produce in such an extent that they could compete with the West-European, American and Asian companies of huge capital power either in productivity, price or product supply [8].

Regarding innovation, the national agricultural machinery manufacturers also significantly lag behind as they can only spend slight amounts on development relative to foreign-owned concerns. As a consequence, loss of market is not surprising as a bit more than one-quarter (26-27 percent) of the current total domestic market turnover comes from domestic manufacturers. The extent of market loss and the general situation of the national agricultural machinery manufacturers justify that the present of this sector must be dealt with by searching the ways-out of the crisis and make steps to develop.

MATERIAL AND METHODS

Our examinations are mainly based on primary research. When formulating the research bjectives, we relied on the theoretical conclusions drawn from the related specialist literature as well as the earlier publications of experts and empiric research results.

The basic objective of the research is to explore and analyse the innovation activity of the national agricultural machinery manufacturers, its results and influencing factors.

The more detailed questions and points of view of the examination that can be derived from the basic question of the research are the following:

- What are the main directions, assisting and hindering factors of the technical development activity of the companies?
- What are the dominant directions and bottlenecks of the agri-technical innovations?
- How can technical development be described compared to the research results of other sectors?

Finally our objective is to have a picture of the innovation activity of the organisations involved, the special features of innovations, the partners taking part in the processes and the impact of innovation on the general situation of the companies through our examinations. Besides the brand-new or significantly developed products and technological procedure innovations, organisational features, marketing activity and the environment of the innovation are also considered. The questionnaire serving as the basis of primary research embraces three years, from 2007 to 2009.

According to the estimations of experts the number of agricultural machinery manufacturing companies is between 100-120 in Hungary. A great part of the enterprises are involved in more than one activity: a lot of predominantly small enterprises are also engaged in other activities besides machinery production so that is why it is difficult to define the actual number of ‘agricultural machinery manufacturers’ exactly. Most of the organisations that are subject to our analysis are small enterprises whose annual revenue does not reach one billion HUF.

As there was not an available list on all the companies on the basis of which a pattern of probability could have been compiled, the companies that could be drawn into the research had to be defined in another way. To find the companies necessary for carrying out the questionnaire, the address list of MEGOSZ (National Association of Agricultural Machinery Manufacturers) served as a basis and the heads of this professional organisation were also consulted.

In the data recording phase of the research a multi-channel approach was applied whose main points are:

- 15 machine manufacturers (hopefully the most significant companies of the sector) were questioned at personal in-depth interviews.
- 25 organisations were provided with a questionnaire sent by post requiring them to send back the material filled in.
- 18 machine manufacturers were questioned at internet-interviews.

Sample-taking cannot be regarded representative. However, during the research it was not our objective to draw conclusions that can be generalised for the basic population. Our basic objective was to give a thorough examination of innovation activity and to achieve it, we tried to select the organisations regarded to be suitable on the basis of preliminary professional considerations. As such a thorough examination dealing with the innovation activity of agricultural machinery manufacturers was not carried out in the past 25 years on a national level, we consider our research is to resolve discrepancies in the professional field.

In compliance with the general methodological requirements first of all some pilot questions were asked on the basis of which the questionnaire was finalised. Data recording took place between March 2010 and August 2010.

The duration of in-depth interviews was various, typically 90-100 minutes per interview. A positive feature of them was that data providers mainly come from the senior management (chief executive officer, head of production or technical manager). In this way first-hand information on the general situation, actual projects and strategic plans of the organisation involved was gained besides the reliability of data. The atmosphere of the interviews was typically of honesty and intimacy. Before starting the interviews we assured our interviewees of the confident nature of the research, i.e. their names and opinions were treated as highly confidential and were not made recognisable for others. Some of our interviewees have already expressed their enquiry in our results.

The questionnaires compiled on the basis of the interviews and sent out by post were also accompanied by a guide to filling in. Seven-ten days after the questionnaires had been filled in, the enterprises were also contacted by phone asking them to cooperate. A kind of evaluation of our preliminary work is that all the responding organisations gave answers that could be assessed.

The statistical processing of data recorded by the questionnaires was carried out by using SPSS 13.0 programme.

RESULTS AND DISCUSSION

The breakdown of the concerned enterprises by size is presented by Figure 1. The types of enterprises based on the number of their employees were considered in accordance with Act XXXIV of 2004 [9]. The breakdown reflects that the SMEs, typical of the sector, are overrepresented. Of the responding enterprises, micro enterprises represent significantly less weight in comparison with the data of the sector. The reason for it is that it was not the objective of our research to analyse them in more details.

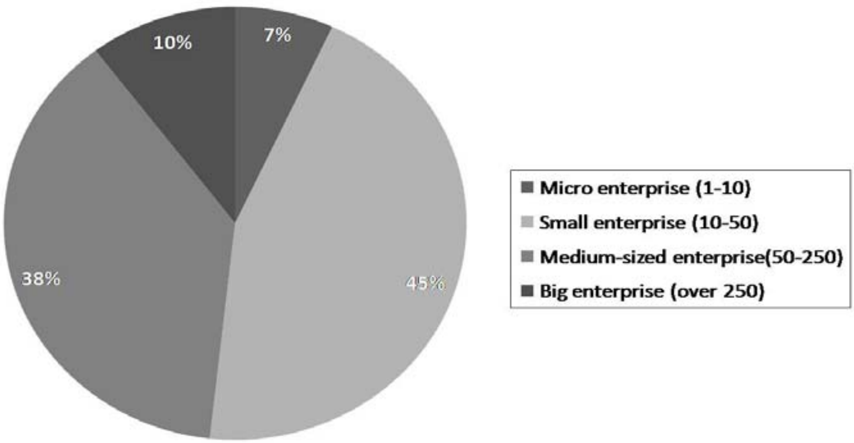

Figure 1. The breakdown of the enterprises concerned by size

In our questionnaires we separately dealt with the analysis of the role of foreign-owned innovation. Twenty-one percent of the companies involved indicated that they had foreign owners or part of its shares in foreign hands. The responses reflected that at companies owned by foreigners in 100 percent the desire for innovation is rather pushed in the background and the tasks of the national subsidiaries are limited to the launch of the products developed by the parent company in their plans and to ensure the maximum cost efficiency in production.

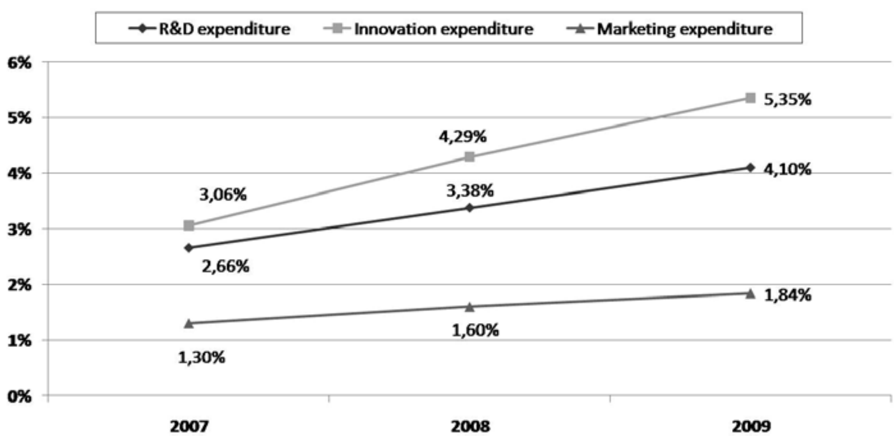

Figure 2: Expenditure on innovation, R&D and marketing

We examined how much of their revenues the enterprises spend on innovation, research-development and marketing (Fig. 2). In our experience the examined enterprises have realised the necessity of innovation in the marked areas. In this respect revenues show an increasing tendency despite the fact that the global economic crisis had several drawbacks in the growth of most companies. The companies spend hardly more than one percent of their revenue on marketing. This can also be explained by the fact that this sector is a typically neglected one as marketing-and advertising costs are the part of expenditures that enterprises can save most of in time of crisis.

We also examined which markets the enterprises realise their revenue (Fig. 3). It was an outstanding fact that the enterprises concerned sold their products on the Hungarian market in 72 percent and during the past three years there has not been a considerable shift in this area. The exact numbers were completed by the in-depth interviews with the fact that one of the main intentions of the enterprises is to break successfully in foreign markets. However, most of them reported failures they faced. The reason for it derives from a lot of factors altogether: although their improved products have excellent value for money, they cannot compete with the local competitors mainly due to lack of a proper channel of distribution. Another problem is the resistance of the West-European farmers to less-known brands. The resources of the enterprises are depleted by demanding developments so they can hardly spend on marketing and PR activities, which would be essential in this sector.

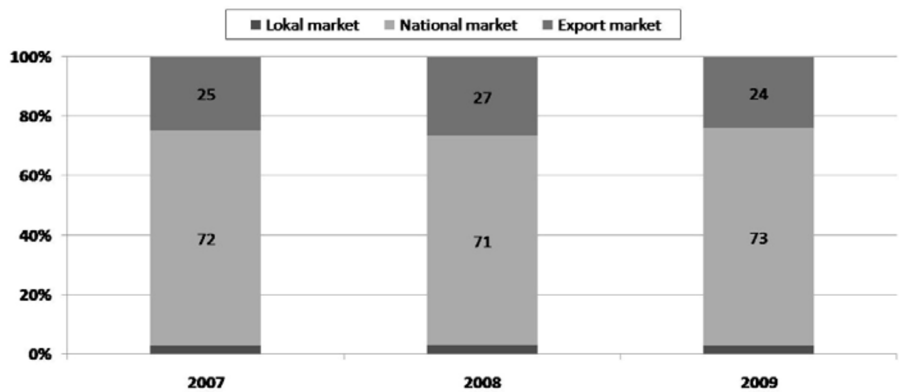

Figure 3. The breakdown of revenue by markets

On the examined timeline 34 percent of the enterprises had a separate R&D department. The picture is made even more complicated by the fact that at the departments of such small-and medium-sized enterprises there are only one or two full-time employees to deal with the questions of innovation on the average compared to the big companies that can afford to operate R&D department with much bigger staff.

In case of the marketing departments, the result was the same as 30 percent of the examined organisations had such a section. In this department typically one person in full time, or rather, part-time is employed to deal with marketing issues.

An interesting finding is that 48 percent of the enterprises operate in a linear while 38 percent of them in a simple organisational form, i.e. they do not have functionally separate organisational units.

Strategy in the competitive market is such a guideline of corporate function that defines the long-term goals and the system of means and methods that are necessary to reach them. Strategic planning plays an important role at all types of companies especially in the case of the innovative ones as it is they who dare to enter an uncertain area in its technical and economic sense due to their special activities [1]. A thoroughly planned conscious strategy is the basis for creating innovations and operating an innovative organisation. Innovation strategy has to derive from and serve corporate strategy. The main point of innovation strategy is how the company can reach the market starting from research and development via product/service/technology production in the easiest way [3]. An effective innovation strategy is implemented in a simple, concentrated way to a small extent so at the beginning scarce resources (funds, labour) are used and, simultaneously, the way out is also considered.

At the time of the research almost 44.8 percent of the responding companies had a written corporate strategy and only 33 percent could present innovation strategy.

Figure 4 illustrates the reason why the respondents decide on investing in innovation. Typically external forces (31 percent) explain why some of them lack a concrete conception on corporate running. Ten percent of them make a decision relying on other's opinion. The interviews revealed that mostly it is the business partner's recommendation and opinion that is reflected in the figures and nearly 14 percent make decisions based on anticipation.

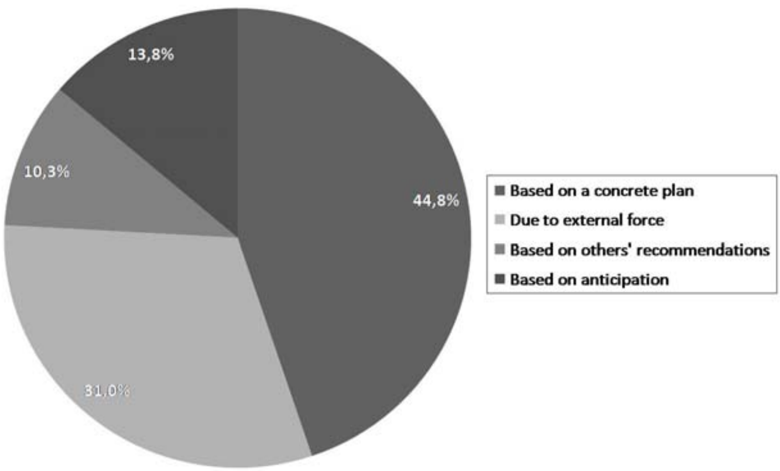

Figure 4. The main motives of innovation investment

Basically, innovation strategies can be of setting or following nature. The setting companies strive to have a leading role based on their technological advantages. At the same time, the application of this strategy incurs higher market and technological risks. It turns out from the examinations conducted so far that only a few national agricultural machinery producers are able to carry out setting innovation strategy. The relevant part of the questionnaire also justifies the statement and 22 percent strive to carry out setting innovation strategy. The follower strategy is more widely uses (88%). The results so far also reflect that the national agricultural machinery manufacturers aim at the user oriented further development of once introduced innovation and technological solutions. As they carry on with their former innovation results, the technical (technological) risk cannot be regarded really significant.

CONCLUSIONS

The characteristics of the Hungarian agricultural machinery manufacturers drawn in the examination illustrate the situation of the sector in the country. A decisive part of the organisations (83%) are small-and medium-sized enterprises. All in all, only about 26-27% of the national need for machinery derives from national manufacturers. Their attitude in development is reflected by the fact that more than 70 percent of their products are sold on the domestic market. As a result of their intention to increase export, one-quarter of their products are launched on foreign markets. Regarding the factors that influence their sales results we concluded that almost one-third of the examined organisations had a separate R&D department and the proportion of organisations that have a separate marketing department is similar.

Among the examined indicators of innovation performance the following ones must be highlighted:

Organisations were spending more and more on R&D in the examined years, in 2009 it comprised 4.1 % of their average revenue. This value means a nominal increase of 154% relative to the one in 2007.

Regarding the main directions of R&D activities it can be stated that most attention is paid to the development of the existing products (71%) and technologies (59%). Fewer companies are willing to deal with novelties, 66% are striving to develop new products and 52% to develop new technologies.

At the time of the research almost 44.8 percent of the responding companies had a written corporate strategy and only 33 percent could present innovation strategy.

ACKNOWLEDGEMENT

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ULOGA STRATEGIJE U INOVACIONIM SPOSOBNOSTIMA MAĐARSKIH PROIZVOĐAČA POLJOPRIVREDNE MEHANIZACIJE

Árpád Bak[1], Zoltán Szira[2]

[1]Univerzitet Szent Istvan, Mašinski fakultet,
Institut za inženjering i menadžment, Gödöllő, Mađarska
[2]Univerzitet Szent Istvan, Fakultet za ekonomiju u društvene nauke,
Institut za javnu administraciju i poslovno pravo, Gödöllő, Mađarska

Sažetak: Trenutna proizvodnja poljoprivrednih mašina u Mađarskoj u velikoj meri zaostaje za proizvodnjom prethodnih godina. Organizaciona struktura mađarske proizvodnje poljoprivrednih mašina je potpuno transformisana, pre svega u pogledu vlasničke strukture. Generalni problem ovog sektora su male investicije u razvoj inovacija u odnosu na strane proizvođače. Posledica toga je gubitak tržišta, tako da ne čudi što malo više od jedne četvrtine (26 -27%) sadašnjeg ukupnog domaćeg prometa potiče od domaćih proizvođača. Stepen gubitka tržišta i opšte stanje nacionalnih proizvođača poljoprivrednih mašina pokazuju da ovaj sektor mora da se bavi traženjem puteva za izlaz iz krize i daljim razvojem.

Zaključci našeg rada su zasnovani na rezultatima ispitivanja preko upitnika i ličnih razgovora sa ispitanicima iz 58 mađarskih preduzeća za proizvodnju poljoprivrednih mašina. Karakteristične odlike kompanija koje su učestvovale u ispitivanju pravilno odražavaju situaciju celokupnog sektora u Mađarskoj. Prema našem iskustvu i izvorima, mađarski uslovi su takođe primenljivi i tipični i za proizvodnju poljoprivrednih mašina u ostalim bivšim socijalističkim zemljama.

U našem radu, pre svega je predstavljen metod empirijskog istraživanja tako što su detaljno prikazani struktura korišćenih upitnika i postupci sakupljanja i obrade podataka. U našem sadašnjem istraživanju prikazani su neki od naših rezultata zajedno sa rezultatima deskriptivne statističke analize. Pored potpuno novih ili visoko razvijenih proizvoda i inovacija tehnoloških postupaka, takođe su predstavljeni i neki od indikatora strategije preduzeća.

Ključne reči: *inovacije, agrotehnički razvoj, ključni faktori inovacija, strategija*

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