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PREFACE

In the name of the Committee of Agricultural and Biosystem Engineering of the Hungarian Academy of Sciences we would like to welcome everyone who is interested in reading our journal. The Hungarian Agricultural Engineering (HAE) journal was published 30 years ago for the very first time with an aim to introduce the most valuable and internationally recognized Hungarian studies about mechanization in the field of agriculture and environmental protection. In the year of 2014 the drafting committee decided to spread it also in electronic (on-line and DOI) edition and make it entirely international. From this year exclusively the Szent István University's Faculty of Mechanical Engineering took the responsibility to publish the paper twice a year in cooperation with the Hungarian Academy of Sciences. Our goal is to occasionally report the most recent researches regarding mechanization in agricultural sciences (agricultural and environmental technology and chemistry, livestock, crop production, feed and food processing, agricultural and environmental economics and energy production) with the help of several authors. The drafting committee has been established with the involvement of outstanding Hungarian researchers who are recognized on international level as well. All papers are selected by our editorial board and a triple blind review process by prominent experts which process could give the highest guarantee for the best scientific quality. We hope that our journal provides accurate information for the international scientific community and serves the aim of the Hungarian agricultural and environmental engineering research.

Gödöllő, 31.12.2018.

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and
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Faculty of Mechanical Engineering

ANALYSATION OF THE EFFECT OF THE CONTACT PARAMETERS ON SOIL'S SHEAR BEHAVIOUR IN DISCRETE ELEMENT SIMULATIONS

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Abstract

Direct shear tests are commonly used in agricultural research to determine the soil's cohesion and internal friction angle. This phenomenon can be modelled using the Discrete Element Method (DEM) very well. In this paper the results of numerical discrete element simulations were presented. The aim of the calculations was to analyse the effect of the Hertz-Mindlin with bonding contact properties on shear force-shear displacement curve. Using these results the contact parameters can be set up to reach similar results in the discrete element simulations and real direct shear test.

Keywords

DEM, direct shear test, Hertz-Mindlin with bonding contact model

1. Introduction

Soil shear behaviour plays an important role in agricultural researches because soils are under significant shear stress when traction force is generated by the driven wheels of the tractors or trucks [1, 2, 3]. Therefore, the mechanical properties of the soil, namely the cohesion and the internal friction angle are important parameters which can be used in the design process of these machines to reduce the stress applied into the soil during tillage operations. One of the most common methods to measure these properties is the laboratory direct shear box test [1, 2, 3].

Discrete Element Method (DEM) was developed in the last century by Cundall and Strack [4] and is widely used in the literature to model cohesive and non-cohesive materials such as soil [5, 6, 7]. In most researches the Hertz-Mindlin contact models are used to simulate soil cutting [5], wheel-rolling [7] etc. where numerical direct shear tests are presented to calibrate the soil material. However, Safranyik investigated the effect of the Hertz-Mindlin with bonding contact properties on soil's cohesion and internal friction angle [8], but there is no publication about the effect of these contact properties on the shear force-shear displacement curve yet. Therefore, the aim of this work to investigate these phenomena.

2. Materials and Methods

In DEM, the importance of the contact models is very high because in most cases only rigid particles are used in the simulations. In this paper the Hertz-Mindlin with bonding contact model was used to model cohesive soil which consists two separate model. The Hertz-Mindlin model [9, 10, 11] is present to model the friction and pressure between the particles and the Parallel Bond model [12] is responsible to simulate the cohesion in the soil.

By using the Hertz-Mindlin contact model the contact force can be divided into normal and shear forces according to the normal and tangential direction of the contact. The contact normal force (F_n) between the particles can be calculated from the normal overlap of the elements (δ_n) by Eq. 1:

$$F_n = \frac{4}{3} \cdot E^* \cdot \sqrt{R^*} \cdot \delta_n^{\frac{3}{2}}. \quad (1)$$

The E* denote to equivalent elastic modulus and R* is the equivalent radius. These can be determined from the parameters, E and R of the contacting particles. In addition, the contact shear force (F_t) can be calculated as:

$$F_t = -S_t \cdot \delta_t = -8 \cdot G^* \cdot \sqrt{R^* \cdot \delta_n} \cdot \delta_t, \quad (2)$$

where G* is the equivalent shear modulus and δ_t is the tangential overlap of the elements. The shear force has a limit; it cannot be greater than the value from Eq. 3 which represents the Coulomb-friction criteria.

$$F_t \leq F_n \cdot \mu_s. \quad (3)$$

In addition, there are damping forces, in normal (F_{nd}) and tangential direction (F_{td}) as well to model the energy dissipation of the collision:

$$F_n^d = -2 \cdot \sqrt{\frac{5}{6}} \cdot \beta \cdot \sqrt{S_n \cdot m^*} \cdot v_n^{rel}, \quad (4)$$

$$F_t^d = -2 \cdot \sqrt{\frac{5}{6}} \cdot \beta \cdot \sqrt{S_t \cdot m^*} \cdot v_t^{rel}, \quad (5)$$

where β can be calculated by Eq. 6 using the coefficient of restitution (e).

$$\beta = \frac{\ln e}{\sqrt{\ln^2 e + \pi^2}} \tag{6}$$

Once the Parallel Bond is formed between the particles, a set of elastic springs are created around the contact point with Bond radius of R^B. The Bond model acts parallel with the Hertz-Mindlin contact model, therefore additional normal (ΔF_n) and shear (ΔF_t) forces are summed to the corresponding components:

$$\Delta F_n = -S_n^B \cdot A \cdot \Delta\delta_n, \tag{7}$$

$$\Delta F_t = -S_t^B \cdot A \cdot \Delta\delta_t, \tag{8}$$

These can be calculated from the cross section (A), the normal (S_n^B) and tangential stiffness (S_t^B) of the Bond and the relative normal ($\Delta\delta_n$) and tangential displacements ($\Delta\delta_t$) of the contacting particles. With Parallel Bonds, moments can be transmitted through the elements in normal and shear direction as well. The value of these moments can be determined from the polar moments of inertia of the Bond (J) and from the particles relative normal ($\Delta\theta_n$) and tangential rotations ($\Delta\theta_t$).

$$\Delta M_n = -S_n^B \cdot J \cdot \Delta\theta_n, \tag{9}$$

$$\Delta M_t = -S_t^B \cdot \frac{J}{2} \cdot \Delta\theta_t, \tag{10}$$

Note that the relative displacements and rotations are set to zero when the Bond is defined at the time of tBond. Each Bond has a limit value of stress (i.e. the Bond's normal (σmax) and shear strength (τmax)) and if one of these limits are obtained, the Bond will break and from the next timestep the contacting particles will move according to the Hertz-Mindlin contact model only. The maximum of the stresses in the Bond can be calculated by Eq. 11 and Eq. 12.

$$\sigma_{max} = \frac{-\Delta F_n}{A} + \frac{2 \cdot M_t}{J} \cdot R^B \tag{11}$$

$$\tau_{max} = \frac{-\Delta F_t}{A} + \frac{M_n}{J} \cdot R^B \tag{12}$$

In DEM, the simulating process is divided into small timesteps of dt, and in each timestep the elements' displacement-vectors (including the translations and rotations of the particles) are calculated according to Newton 2nd law. The value of dt has great effect on simulation results, it should be small enough to capture great impacts between the elements. But by choosing small timestep, the calculation time will be increased dramatically. To set up the correct value of the timestep, the EDEM User Manual [13] makes a suggestion, namely it should be in the range of 0.1… 0.2 times of the Rayleigh timestep ($t_{Rayleigh}$). In our simulations this was taken into account which resulted that the calculations were performed with timestep of 5e-06 s.

3. Real direct shear test and discrete element simulations

To compare the results of the discrete element simulation with real measurement values, direct shear tests were conducted in the laboratory of the Szent István University of Gödöllő, Institute of Process Engineering. First the soil samples were transported to the laboratory in core cylinders, and after that the tests were carried out using the ELE 26-2112/01 type direct shear apparatus (Figure 1). The samples were loaded vertically with the load force of 400 N, and the shearing process was started with the speed of 5 mm/min. During the process, the force acting on the top cylinder of the shear box assembly (as shear force) and the horizontal displacement of the top cylinder (as shear displacement) were measured. Note that the vertical displacement of the samples was not measured during the measurements. The diameter and the height of the top and bottom cylinder as well were 60 mm and 12,7 mm, respectively.

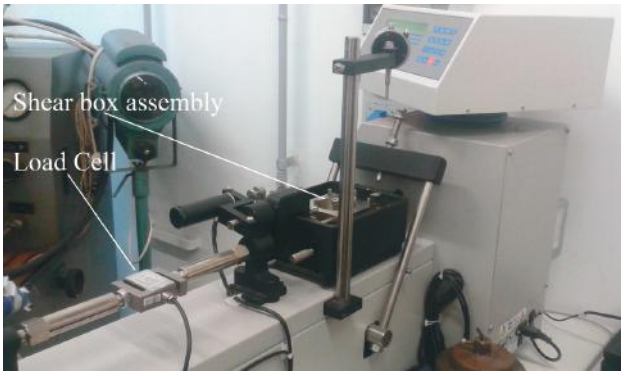

Figure 1. The ELE 26-2112/01 type direct shear apparatus.

The same geometry of shear box assembly where created in EDEM 2.7 software environment. The cylinders were filled with spherical elements with radius of 1,33…3 mm, and after the whole system obtained the equilibrium state (the maximum of the elements velocity got smaller than 0,01 mm/s) the Parallel Bonds were installed between the particles. Then the vertical force of 400 N (i.e. the normal load) was applied on to the top of the model through a clump element, shown as grey colour in Figure 2. Finally, the top section of the assembly was moved horizontally with the speed of 50 mm/s which is 10 times higher than the used shearing speed in real direct shear tests. This was chosen to minimize the calculation time of the discrete element simulations and according to our earlier research it has negligible effect on the results.

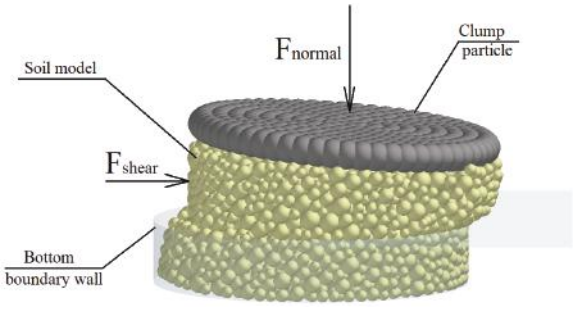

Figure 2. Numerical direct shear tests.

Some of the contact properties of the first model (shown in Table 1) were set up according to the calibration process presented in our earlier research [14] and the remaining contact parameters were chosen for sensitivity test:

- particle's shear modulus,
- particle's Poisson-ratio,
- particle's density,
- Parallel Bond radius, and
- Parallel Bond stiffness.

Table 1. The properties of the first discrete element soil model

Parameter	Value
Geometrical properties	
Particle radius distribution (mm)	1,33…3
Contact radius (mm)	1,6…3,6
Initial porosity (before the normal load applied) (-)	0,425
Properties of the Hertz-Mindlin with bonding contact model between the soil elements	
Density (kg/m^3)	1,8e+03
Shear modulus (Pa)	1,44e+07
Poisson ratio (-)	0,25
Coefficient of restitution between the soil particles (-)	0,5
Coefficient of restitution between the soil particles and walls (-)	0,5
Friction coefficient between ball and ball (-)	0,4
Friction coefficient between ball and walls (-)	0,6
Bond radius (mm)	1,5
Bond normal stiffness (Pa/m)	9,5e+06
Bond shear stiffness (Pa/m)	9,5e+06
Bond normal strength (Pa)	3,131e+4
Bond shear strength (Pa)	4,428e+4
Properties of the Hertz-Mindlin contact model between the cylinder (wall) elements	
Density (kg/m^3)	7,8e+03
Shear modulus (Pa)	7,692e+10
Poisson ratio (-)	0,3
Coefficient of restitution between walls (-)	0,5
Friction coefficient between wall and wall (-)	0,1

Discrete element simulations were performed with different values of these properties (Table 2) and their effect on simulation results, namely the shear force-shear displacement curve were analysed. Our aim was to determine which contact parameters have significant effect on the process of soil shearing and therefore is necessary to take into account while calibrating the properties of the soil model to the measurement results.

Table 2. The value of the contact properties in the sensitivity test.

Parameter	Range of value
Shear modulus (Pa)	1,44e+06… 1,4e+08
Poisson ratio (-)	0,2…0,3
Density (kg/m^3)	1,6e+03… 2,0e+03
Bond radius (mm)	0,5…3,0
Bond normal and shear stiffness (Pa/m)	9,5e+06… 4,75e+07

4. Results and Discussion

In this section, the results of the discrete element simulation are presented.

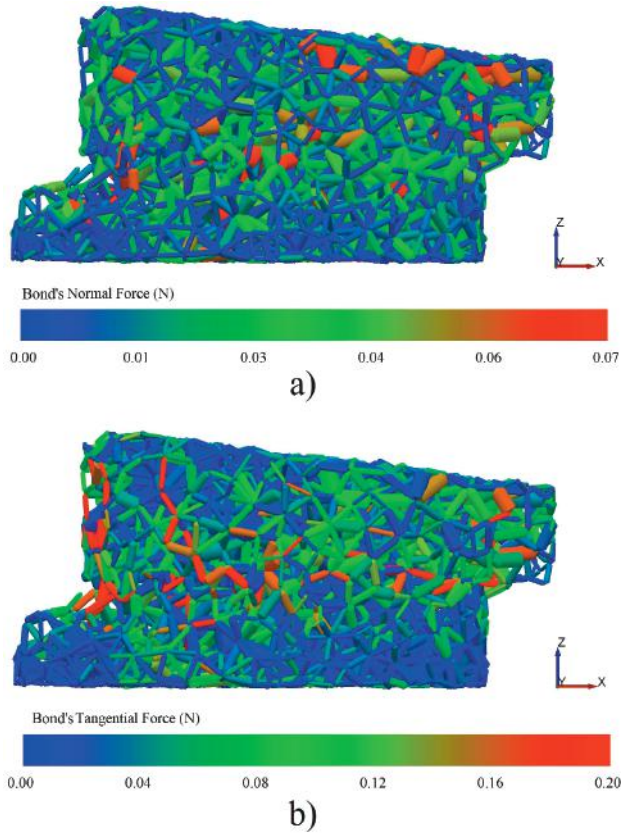

Figure 3. The Parallel Bonds between the particles.

First the results were checked qualitatively to be sure that the simulation process is similar to the real direct shear test. Thus, the Parallel Bonds with their normal and tangential forces and moments were investigated. In Figure 3, the Bonds between the elements are shown as beams, and are coloured according to the Bond's normal and tangential force in the part of the figure a) and b), respectively. It can be seen that the highest forces arise in the shear zone and on the top of the soil, where the normal load is applied. We concluded that the axial and shear moments in the bonds are much smaller, thus has negligible effect on the normal and shear stresses on the Bond according to Eq. 11 and Eq. 12.

So it can be asserted that the highest Bond's stresses arise near the shear zone which is a good result when comparing the calculations to the theoretical process.

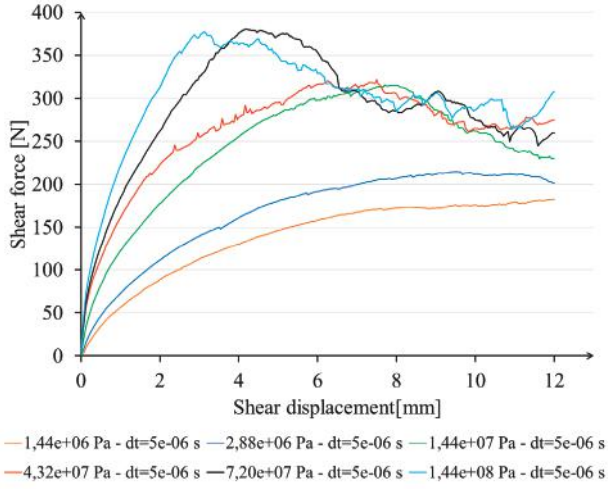

Figure 4. Effect of the particle's shear modulus.

In Figure 4, the effect of the particle's shear modulus is shown. It can be clearly seen that this property has great effect on the shear force-shear displacement curve. By increasing the value of the shear modulus, the maximum of the shear force is increasing as well while the displacement, where these maximum forces arise, is reducing. According to these results, it can be asserted that the shear modulus of the elements has great effect on the gradient of the curve. Note that in case of shear modulus value of 1,44e+07…4,32e+07 Pa the characteristic of the curve is changing; in case of smaller shear modulus one can get the so-called asymptotic shear force-shear displacement curve which is typical in case of loose or non-cohesive soils [1, 2, 3]. On the other hand, in case of high particle's shear modulus, the curve has high peak forces which can be measured in cemented, cohesive soils [1, 2, 3].

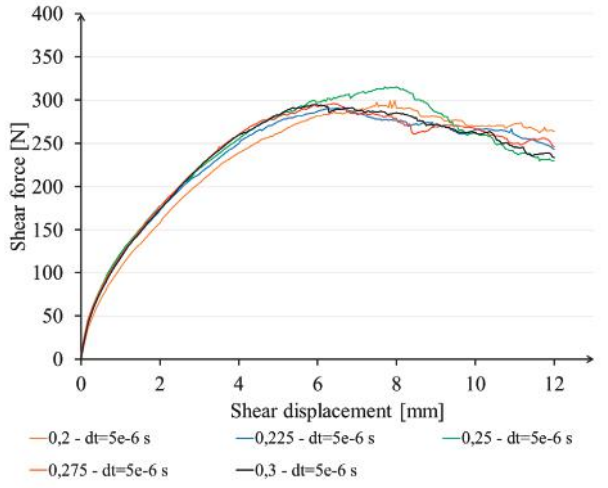

Figure 5. Effect of the particle's Poisson ratio.

After the shear modulus, the Poisson ratio and the density of the particles were analysed, the results can be seen in Figure 5 and Figure 6. It can be asserted that in the range of value of these contact properties, there is no significant effect on the shear force-shear displacement curve.

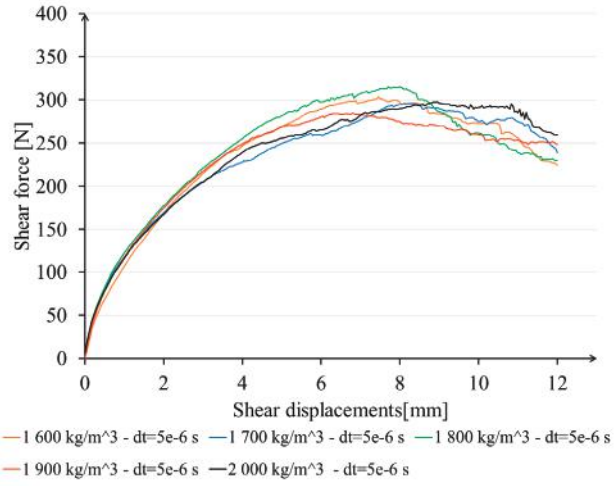

Figure 6. Effect of the particle's density.

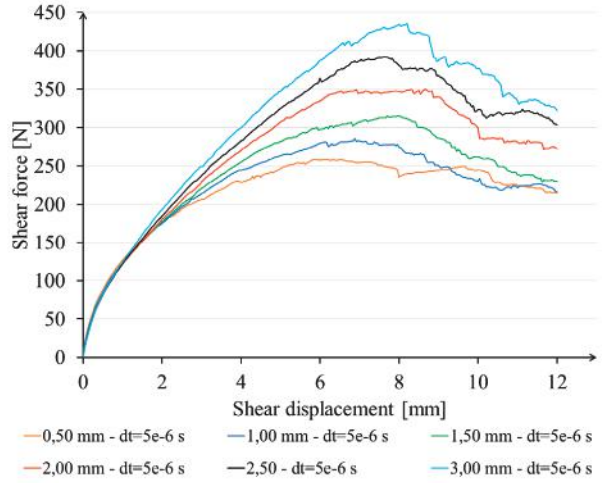

Figure 7. Effect of the Bond radius.

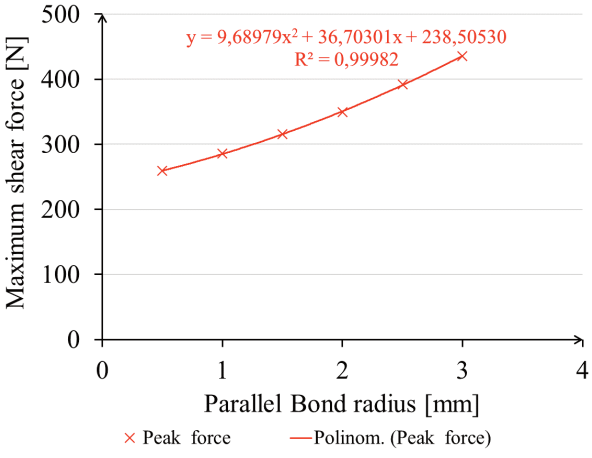

Figure 8. Effect of the Bond radius on the maximum of the shear forces.

Finally, the properties of the Parallel Bond contact model, namely the Bond radius and stiffness were analysed. In Figure 7, it can be seen that by increasing the Bond radius, the peak force

and the displacement, where these forces occur, is increasing as well. But this contact parameter has negligible effect on the gradient of the curve in the range of shear displacement of 0…2 mm. In Figure 8, the peak forces are presented in a function of Parallel Bond radius. It is shown that a quadratic polynomial curve can be fitted to the points with high value of R2 using the Ordinary Least Squares method. This can be used further to estimate the value of the peak force in case of varying Parallel Bond radius. Note that the quadratic polynomial curve was chosen because according to Eq. 7 and Eq. 8, the normal and shear forces in the Bond is proportional to the area of the Bond, thus to the 2nd power of the Bond's radius.

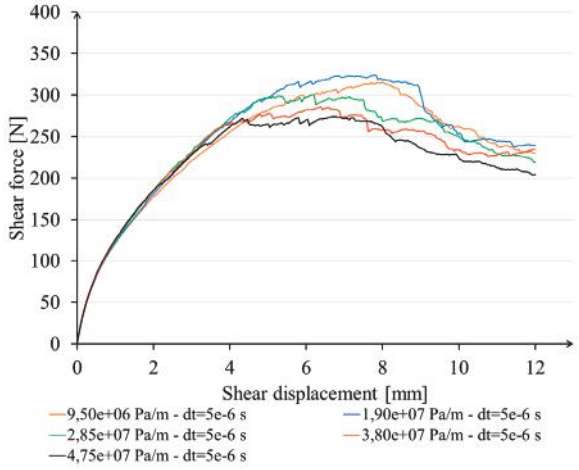

Figure 9. Effect of the Bond stiffness.

In Figure 9, the effect of the Bond's stiffness is shown. By changing the value of this parameter, the shear force-shear displacement curve is modified a little bit, the peak force is slightly different in the investigated five cases. But this difference is negligible, the first sections of the curves (in the range of displacement of zero to 4 mm) are almost exactly the same. So we concluded that this parameter is not so important in the calibration process of cohesive soils as the particle's shear modulus and the radius of the Parallel Bond were.

After the effect of the contact parameters was determined, our aim was to calibrate the properties of the model to the shear force-shear displacement curve, measured during the laboratory direct shear tests. So the Parallel Bond radius and the shear modulus of the particles were set up correctly (Table 3), the other parameters remained the same as were in the first model.

Table 3. The calibrated value of the contact properties derived from the results of the sensitivity test.

Parameter	Range of value
Shear modulus (Pa)	1,488e+07
Poisson ratio (-)	0,25
Bulk density (kg/m^3)	1,8e+03
Bond radius (mm)	0,93
Bond normal and shear stiffness (Pa/m)	9,5e+06

Figure 10 shows the results of the simulation observed with the calibrated/final contact properties. Up to the displacement of 10 mm the shear force-shear displacement curves from the calculation and measurement are very similar which is a very good result. This means that this soil model is able to simulate the failure of cohesive soil properly, thus can be used in all cases, where the normal load of the soil is similar to the load in the direct shear test (e. g. in case of wheel rolling on deformable soil with similar vertical load).

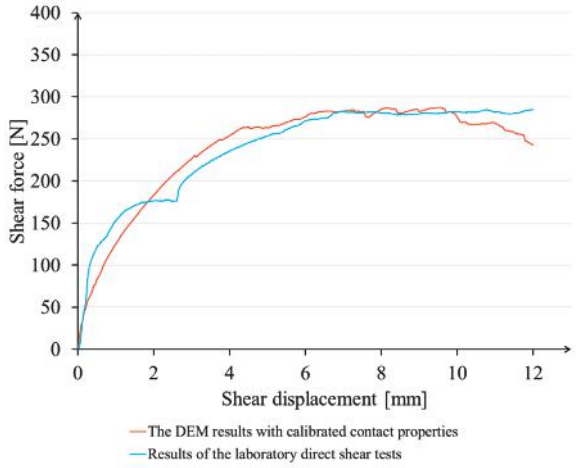

Figure 10. Comparison of the shear force-displacement curves from the measurement and from the simulations.

5. Conclusion

In this paper the discrete element method was adapted to simulate cohesive soil's direct shear test. The aim of our work was to determine those properties of the Hertz-Mindlin with bonding contact model, which has significant effect on shear force-shear displacement curve. As a results, we concluded that these parameters were the particle's shear modulus and Parallel Bond radius. The other investigated parameters (including the Poisson-ratio, the density of the elements and the Parallel Bond stiffness) has negligible effect on soil shearing process, thus can be ignored while calibrating the discrete element model to the result of real measurements. The remaining contact properties can be set up using our earlier research.

The soil model with final contact properties was able the simulate the real direct shear test properly, thus it can be used in additional simulations where soil shearing plays important role (i. e. wheel rolling, soil cutting). On the other hand, the results can be used to develop a calibration process for direct shear simulations.

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Faculty of Mechanical Engineering

FINANCIAL INCLUSION AND AGRICULTURAL PERFORMANCE OF SMALLHOLDER FARMS IN MBANKOMO COMMUNITY

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Abstract

The study has attempted to carry-out a comprehensive analysis on the impact of Financial Inclusion on Agricultural Performance among Smallholder Firms in Mbankomo Community. The social and economic gap between the welfare of the rural and urban inhabitants as well as agricultural and white collar job is very alarming in developing countries. To close this gap, this study identifies the different financial services available for farmers; explore the contribution of financial inclusion on agricultural performance and to analyze the constraints face by farmers in production. Methodologically, we make used of Multiple Correspondence Analysis to construct a synthetic indicator for financial inclusion. Considering the control variables, financial inclusion index is regress on agricultural performance through the use of Multinomial probit. The result shows that among a host of financial services, farmers are only aware of access to credit, account operation and mobile money services. Financial inclusion is observed to be strongly correlating with agricultural performance, while result by constraints revealed that, the lack of finances; inadequate farm land and variability in climatic conditions are major challenges to agricultural performance in the Mbankomo community. We suggest, decision makers organize workshops to educate farmers on the existence and use of financial service; this is an important step towards increase agricultural production.

Keywords

Financial Inclusion, Agricultural Performance, Smallholder firms, Mbankomo Community

1. Introduction

Financial inclusion is a subject that is increasingly being investigated in economics. It is recognized as an effective means to fight poverty and promote inclusive growth [1]. Financial inclusion, defined as the use of formal financial services, crucially determines economic development. In other words, financial inclusion (or inclusive finance) is the provision of low cost basic financial and banking services to consumers in difficulty and excluded from traditional services. Individuals who are not financially excluded are able to invest in education and start businesses; which contribute to poverty reduction and economic growth [2]. Financial inclusion is therefore the opposite of "banking exclusion" which is directly related to social exclusion.

According to World Bank [3], more than 50 countries around the world have committed to financial inclusion, for example, Nigeria, aims to increase the use of adult payments services by 21.6% in 2010 to 70% in 2020. Rwanda intended to increase access to formal financial services from 21% to 80% by 2017 as was declared in September 2011. World Bank Group President Jim Yong Kim launches global challenge of universal financial access by 2020, and the global development community has continued to support microfinance while working hard in favour of the overall goal of achieving financial inclusion [4].

In Sub Saharan Africa (SSA), mobile technology has significantly strengthened financial inclusion. Now, 34% of adults have an account against 24% in 2015, 12% of adults in the region have a mobile banking account against 2% worldwide. Kenya leads the way with 58% telephone account holding rate compared to around 35% for Tanzania and Uganda. About 13 countries in the region have a telephone banking penetration rate of 10% [5]. Cameroon has made remarkable progress in the last decade, when the mobile phone penetration rate rose from 9.8% in 2004 to almost 50% in 2016 (the country's telecommunications regulator). However, mobile banking services, which include mobile bank accounts, money transfers, cash withdrawals, are still used by a small part of the population, including those with a mobile phone. The explosion of telephone use in the country is an excellent opportunity to develop mobile banking services, which can increase the bank rate in Cameroon [3]. Despite this evolution, it is still necessary to reach the stage of countries like Kenya where mobile payment in 2012 counted nearly 15 million users out of a population of about 43 million inhabitants. In Côte d'Ivoire, Somalia, Tanzania, Uganda and Zimbabwe, more adults use a telephone bank account than an account with a financial institution [3].

In Kenya, more than half of adults pay their utility bills by mobile phone. In Tanzania, almost a quarter of people receiving payments for the sale of agricultural products receive the funds in an account over the phone. In SSA, 48% of adults are emitters or recipients of domestic remittances. If payments related to domestic remittances were made to bank accounts rather than money transfer agent counters, the rate of holding of accounts could double in Senegal, Cameroon, the Democratic Republic of

Congo and the Republic Congo [3]. According to Guieze [6], more than 50% of unbanked people in SSA mention the cost (opening costs of a formal account) as an obstacle to opening a bank account.

Today, more than 2.5 billion adults and more than half of the world's active adults, are excluded from formal financial services. This problem particularly affects low-income populations in emerging and developing countries, where nearly 80% of poor people do not have access to these services. However, their integration into the formal economy is essential for reducing poverty, reducing inequality and promoting inclusive growth [1]. The poor are generally excluded from opportunities in the formal sector. They live and work in the informal economy, not by choice but by necessity. They are both producers and consumers and need access to financial services to build capital, create and maintain livelihoods, manage risks and regulate their consumption. Without access to formal financial services, poor families can only rely on informal mechanisms: family and friends, tontine programs, pawnbrokers, loan sharks and "money hidden under the mattress". These informal mechanisms are neither sufficient nor reliable and are often very costly. Thus, financial exclusion has enormous opportunity costs for those most in need of these opportunities [5].

Finance has been recognized as a driver of economic growth, direct and indirect linkages between finance and poverty reduction have been established by several researchers [7, 8]. Access to financial services is considered an important aspect of development [9]. Improved affordability improves living conditions in many areas: nutrition, health, education and housing [1]. At the macroeconomic level, the affordability of low-income households and producers helps to balance opportunities in terms of access to and use of financial services, reducing inequalities and poverty among the population, and to increase production [10]. Access to financial services is prerequisite for employment, economic growth and poverty reduction [11]. On the micro level, financial services help smallholders for a variety of purposes: production (building of assets and working capital); ensure their protection (mitigate exposure to risks, including health risks); purchase livestock, equipment and agricultural inputs; maintain the infrastructure; hire labour for plantations and crops; transport products to the markets; make and receive payments; manage peak season revenue streams to cover expenses during the low season; invest in training, housing and health and cope with emergencies [3].

Today, most of the world's food is produced by small family farms, paradoxically, 80% of people who suffer from hunger are farmers. Their farm income is often not enough to support their families. The key to achieving poverty reduction and food security is a substantial increase in net income from agriculture, through sustainable, diversified and productive agricultural practices as well as improved market access [11]. It also requires access to productive credit. In the current context of phenomena such as population growth, rural depopulation, the restructuring of production chains and climate change, the need for adequate financing for agriculture is increasing. Market-oriented agriculture is part of the product chains that go from the producer to the distribution to the final consumer in the city through the stages of processing and trade [3].

Agricultural production is usually the weak link in the chain because it is represented by the "weakest" actors in the chain and includes the most risk. Family farmers unite sometimes their strengths to maintain the added value at their level in order to strengthen themselves compared to other actors in the chain. That's why agricultural lending is an essential lever that often becomes the limiting factor. In turn, agricultural credit is generally facing structural challenges because the financial performance of family farms and cooperatives is limited and riskier than other links in the chain [11]. The accessibility of bank branches is often problematic and financial service providers are mostly urban dwellers who are not sufficiently familiar with agricultural and rural production.

Since farmers in developing countries, as a general rule, are less educated and have little or no knowledge of the products and requirements of financial institutions. Agricultural enterprises in developing very rarely have formal titles of land ownership; hence, neither their land nor any agricultural building can serve as a guarantee for them to collect loans from banks. Financial inclusion has grown strongly in recent decades to allow these individuals and to these companies to access basic financial services (deposits and money transfers, payments, savings, credit, insurance) [9]. In addition to credit and savings services, rural microfinance seeks to meet other financial needs: households and individuals need insurance to cover health risks, risks related to economic activity. The challenge for micro finance is twofold: first, to better meet the needs of rural populations, as well as to expand and diversify its own portfolio of activities and secure this portfolio of activities. For example, health insurance helps to secure the activities of an agricultural producer and in so doing secure the credit for these activities [10]. As a step to solving this issue, the objective of this study is to: assess the effect of using financial services on agricultural performance, identify the different financial services available to agricultural stakeholders and to determine the agricultural constraints faced by farmers of Mbankomo community.

2. Literature Review

Many studies have been done to highlight the impact of financial services on agricultural development. Some of these studies were done in Brazil where a large credit program had been developed [12]. All these studies do not lead to concordant conclusions. An analysis by Rao [13] showed that there is an underutilization of capital in small farms and that a credit program can remove this constraint to improve the productivity of these farms. The World Bank [3] estimated that credit is needed for small farmers to increase their agricultural productivity and income, though, their access to formal credit is restricted. However, simply recognizing credit as a condition for agricultural growth is not enough to guarantee increased productivity and farm incomes.

Mbata [14] believed that financial services are useful for increasing the efficiency required by small farmers. Ledgerwood [15] noted that farmers in Africa have demonstrated that where there is an opportunity to earn higher incomes, they can be dynamic producers. Kitbur [16] showed that the modernization of agriculture requires an increase in the use of modern inputs and consequently, an increase in the demand for credit. However, Levine [17] conducted a study on agricultural production in Ribeirao and found that there are technological barriers that could prevent farmers from being effective even if they have access to credit. Several studies showed similar results [18]. Above all, Seteitieh [19] showed that increased investment in factors of production such as mechanization equipment and fertilizers is not enough to increase production. An effective management and information system for farms needs to be put in place. In other words, farmers with access to credit can buy modern factors of production, but this does not always guarantee the proper use of these factors.

Levine [17] conducted a study on the impact of credit on the income of rice farmers in the Senegal River Valley. The "treatment effect" method is used to assess the impact of access to credit on income. The impact of credit on demand by type of input is indeed positive and of high magnitude. However, the efficiency of their use depended very much on age, level of experience and education as well as access to credit. These factors

lead to good cultural management and technical efficiency. The impact of access to credit is almost nil on the technical efficiency and income of the poorest and poorest producers. Credit delay has negative effects on the appropriate use of inputs. Thus, there is an increase in charges without a proportional impact on the level of performance. The impact of access is, on the other hand, beneficial to the average and rich producers who have palliative means to guarantee the delivery of the inputs in time and sufficient quantity.

Ramji [20] studies the role of institutional and socio-political factors in the growth of agricultural production of 41 SSA countries over the period of 1961-1999. It finds that the quality of the workforce, as measured by adult illiteracy, has no significant influence on the agricultural performance of these countries. By studying the relationship between farm size and productivity in Turkey from the 2000-2001 data, Narayanan and Gulati [21] found that a high level of education of family farm managers increases their efficiency, i.e. to say their managerial capacity and therefore their production. Rao [13] study the relationship between transgenic varieties and the production of smallholder cotton farmers in China from 1999 data and found that human capital variables have a positive influence on agricultural production. Jamison and Lau [11] examined the production of peasant agriculture in Ethiopia from 1990-1991 and found that the experiences acquired under parental supervision do not exert a significant influence on production. The authors further, found that the influence of education, cultural knowledge and the number of technologies adopted is greater and that these factors relate to the skills of decision-makers who incorporate indigenous knowledge and acquired knowledge of the subject.

Porteous [22] analyzes the evolution of total factor productivity and its components in the agricultural sector in 16 African countries over the period 1970-2001 and found that illiteracy is negatively correlated with production. By breaking down total factor productivity into its usual two components (technological change and technical efficiency), he observed that productivity growth in the countries studied is mainly attributable to technical efficiency, that is, the ability of the managers, rather than technological progress. The author concluded that improving the understanding of fundamental processes makes more efficient use of available resources, which has a positive influence on production.

3. Methodology

The municipality of Mbankomo is located in the centre region of the Mefou and Akono division. The municipality spread over an area of 1,300 km², bounded in the north by Okola, Lobo and the city of Yaoundé which is located 22 km away, to the west by the town of Matomb, in the south by Ngoumou and Bikok and finally to the east by the Mfou community. The Mbankomo community is influenced by the Equatorial Guinean climate at four seasons of unequal duration: a long dry season from November to mid-March, a small rainy season from mid-March to mid-June, a short dry season of mid June-mid August, a great rainy season from mid-August to the end of October. The average annual rainfall is 1577 mm. The average annual temperature is 25 C with average annual amplitude of 2.5C. This climate favours the annual conduct of two cropping seasons.

The municipality of Mbankomo has a low relief and varied terrain (presence of plains, hills and valleys) with slopes between 0 and 5% reflecting a low sensitivity to erosion. The average altitude is around 720m. As for soils, the parent material is essentially composed of granites. Two main types of soils are found in this locality, namely ferralitic soils and hydro-morphic soils. In general, ferralitic soils are characterized by a sandy loam texture. They are poor in nutrients, acidic, fragile and characterized by strong yellow or light yellow stains under the forest cover, these soils are sometimes clayey, porous, very permeable and rich in humus. They are recognized as very fertile under the forest cover, however, this fertility is quite precarious. These soils lend themselves mainly to perennial crops (cocoa, fruit, and palm) and food crops. The hydro-morphic soils are mainly found in marshy areas and near water courses. The exploitation of these soils is difficult in rainy weather because of their water logging. The hydrographic network is dense in the region and consists mainly of small rivers with steady or seasonal conditions such as Mefou.

Agriculture occupies more than 90% to 95% of the active population, being subsistence agriculture; it focuses in particular on food crops and especially cassava which holds the upper hand. Indeed, it remains the most cultivated speculation both at the individual level, associations and common initiative groups (CIGs) on areas ranging from one to twenty hectares but for some CIGs, this area can go to 25 hectares. Other speculations are: cocoyam; plantain, maize, peanuts, sweet potato, yams, market gardeners (tomatoes) and even NTFPs such as cola, wild mango, hazelnuts, okok and others. It should be noted that these crops are mostly cultivated by women. They are the subject of intense commercial activity and turn cassava into sticks and flour. As for cash crops, there are cocoa, oil palm and fruit trees. This activity remains concentrated in the hands of women and elites.

Fish farming is fairly well practiced in the community and in some villages; it is the object of a sustained exploitation which attracts the people in search of distraction. Fishery products have an important place in the supply of animal protein to households. Fishing is artisanal and is practiced on the main rivers; it is the responsibility of young people and women. Fishing techniques used include the net, dam, line and chemicals (though not healthy to the environment and human health). This activity has interruptions in September and October and then has periods of intense activity during the months of June to August and from November to January. The most-fished species of fish are: Nile tilapia, snake fish, red-tailed fish and freshwater captain among others.

Data Setting

The data used in our study will be from primary sources that will be collected in the field based on producer survey. We took as a sample frame the farmers, having at least five years of experience in the field. For the choice of the sample this will essentially be done by random sampling. The study will be carried out on 150 agricultural farmers.

Econometric Model

In this study, we use the economic model of the family as applied by Blau and Grossberg [23]. This is the conceptual basis for our analysis of the contribution of financial inclusion to agricultural development. On the basis of this family model, the relationship between financial inclusion and agricultural performance can be expressed as follows:

$$P\left(PA_n = j / z_n = z\right) = \frac{\exp\left(z'\alpha_j\right)}{1 + \sum_{1} \exp\left(z'\alpha_1\right)} \quad (1)$$

Where PA_n is the variable that represents agricultural performance and is our dependent variable. This variable has three categories (decrease, remain the same, increase), Z_n is a vector that groups all the factors that can affect agricultural performance such as financial inclusion associated with other independent variables such as: education, the size of the field exploited, the work of households. The financial inclusion

services that could possibly influence agricultural performance such as mobile money, savings, account services, express financial services and lending services. The *j* coefficient is the main parameter of interest and represents the impact that the financial inclusion indicator has on agricultural development while representing the impact of other factors that could complement financial services to influence agricultural performance.

The equation is a Multinomial Logit Model (MLM) that can be used to generate estimates that measure the marginal effects of financial services on agricultural performance. The MLM estimate is an appropriate estimate in this type of study because it attempts to capture the impact of all financial services on agricultural production.

The MLM can be viewed as a special case of the conditional logit model. Suppose we have a vector of individual characteristics Z_i of dimension K and J vectors of coefficients each of dimension K, and then defined

$$X_{i1}=\begin{pmatrix} z_i \\ 0 \\ . \\ . \\ 0 \end{pmatrix},\ldots\ldots\ X_{iJ}=\begin{pmatrix} 0 \\ . \\ . \\ 0 \\ z_i \end{pmatrix}, andX_{i0}=\begin{pmatrix} 0 \\ . \\ 0 \\ . \\ 0 \end{pmatrix}, \quad (2)$$

The defined the common parameter vector *j* as

$$j'=(\gamma'_1,\ldots,\gamma'_1) \quad (3)$$

From the two equations, we can compute for the marginal effects of financial services on agricultural performance by estimating the coefficient *j* of the parameter of interest. This means that our model will be zero biased and our results will be robust.

3. Empirical Results

The socio-economic characteristics of smallholders firms

From our field survey, the socio-economic characteristics of smallholder farmers shows that 51.7% of small producers are men and 48.3% are women. This is similar to those of Ramji [20] who found that 90% of farmers are men and 10% are women. Other authors also point to a predominance of men as farmers [24]. This can be explained by the intensive physical work required for agricultural production. We also observed that the majority of farmers are older than 50 years, i.e. 44.2% of the sample. Young people less than 35 years represent only 3.3%, this can be explained by the fact that they consider agriculture as a painful, boring and low class activity and so they prefer to move to urban centers to seek for white collar jobs small jobs. About 24.2% of farmers have a secondary education, Chidzero et al. [25] note that very few farmers pursue higher education (10%). We note in summary that the level of education here is lower; this refers to the results of the work of Bruhn and Love [5] who states that 43% of farmers are illiterate. Level of education is a form of human capital development that increases labour production, usually resulting in higher output. This analysis show that 62.5% of farmers are married compared to 0.8% who are not married. This can be explained by the fact that, in rural areas, marriage is highly encouraged at young age.

It appears that 40% of farmers had a household size of more than 5 persons under their roof, the work of Claessens [26] illustrate similar results. The large size of the household is usually the cause of poverty in large families with insufficient financial resources. We equally observed that 76.7% of farmers have never attended training seminars against 23.3% who have already had to attend. This gap is reduced over the years, this is explained by the fact that the Cameroonian government has set up several programs of extension and monitoring of agricultural activities for the revival of this sector. However, this needs to be further intensified to cover a large part of the population. Many farmers exploit an area equal to 10000m^2 (21.7%), a large number exploits an area of between 5000 and 7500m^2 (40.8%). This can be explained by the fact that most farmers do not have enough financial means to acquire large farm land, so they content to exploit small farms on which they can bear the costs of production.

Identification of Different Financial Services

Table 1 shows that 13.33% of producers have a bank account compared to 86.66% who do not. It can be seen that bank accounts are available in Mbankomo but very few producers use them. This result is similar to that of the 2014 annual report of the Africa Franc Zone. In relation to access to credit, 36.66% have access to credit against 63.33% who are not, so this service exists in the locality of Mbankomo but remains restricted. These results are very similar to those of Bruhn and Love [5] who found that only 16% of small farmers have access to credit. This can be explained by the lack of collateral to obtain loans from financial institutions. Other reasons include: risk aversion for farmers who are afraid of going into debt, low savings rates, high interest rates, and reluctance of MFIs to provide credit for agricultural activity that is very risky. The various financial services found in the locality of Mbankomo are grouped in Table 1:

Table 1. Financial Services Available in Mbankomo

Financial Services	Total	Available	Not Available	Différence
Bank account	120	0.13333 (16)	0.86666 (104)	-0.73333 (-88)
Access to Credit	120	0.36666 (44)	0.63333 (76)	-0.26666 (-32)
Mobile Financial Services	120	0.56666 (68)	0.43333 (52)	0.13333 (16)
Deposits and transfer money	120	0.84166 (101)	0.15833 (19)	0.68333 (82)
Savings account	120	0.4500 (54)	0.5500 (66)	-0.1000 (-12)

Mobile financial services are available in the municipality of Mbankomo because a large number of producers (56.66%) use these services. This result is close to that of the Telecommunication Regulatory Agency of Cameroon, which has noted that over the last ten years the mobile service utilization rate has increased from 9.8% in 2004 to almost 50% in 2014.

Several producers (84.16%) use the deposit and transfer of money. This service is available (68.33%) and used by a large number of producers. This situation can be explained by the fact that the use of this service is easy, fast and inexpensive for the population. For savings accounts, 45% of producers have an account against 55% who do not. So this service is available but remains to be valued. This result is similar to that of Aguera [4], who found that only 24% of adults had a savings account in a formal financial institution in SSA, compared with an average of 50% worldwide and 89% in the world high-income country. This can be explained by the fact that the rural population has a low income, a lack of information on the functioning of financial systems. However, the number of farmers who continue to save in informal networks (tontines) is non negligible.

Financial Inclusion and Agricultural Performance

The result in Table 2 allows us to observe an overall significance of the model, measured from Chi-square (90.541; 0.000) which is significant at 1%. This model is good for predictions given that Pseudo R-squared of this model is equal to 0.0256 meaning the explanatory variables are closely related to the variable of interest. The result of the multinomial logistic model show that the variables that have a significant impact on agricultural performance are: financial inclusion complemented by variables such as: chemical use, marital status, cultivated area, age, level of education, sex, and age variable that interests us mainly: financial inclusion. Variables such as: household size and training in agriculture have no significant influence on agricultural performance. This can be explained by the fact that small producers have requirements other than those provided by these variables.

Financial inclusion indicator is our main independent variable; it emerges from the result of the multiple correspondence analyses using a host of financial services as indicated in Table 1. From the multinomial logit model, this variable shows that on 75 percentage point financial inclusion is strongly influencing agricultural production, positive and significant at 1%. The probability for an individual making use of financial services to increase agricultural production is greater than otherwise. This result is confirmed by the work of Mbata [14], who found that financial services are useful for increasing the efficiency needed by smallholder farmers; and Aguera [4] observed a positive and significant relationship of access to credit on production. They show that small producers with access to financial services are 8.59 times more productive than those without access to these services. This is because production requires increased input consumption (improved seeds, skilled labor, chemical and organic fertilizers, phytosanitary products) which is very expensive. Other authors report from the results of their studies that access to agricultural credit allows rural producers to increase their production and at the same time their income.

On the contrary, the work of Helms [10] and Aguera [4] confirmed that most poor people instead use their credit to solve social and non-productive problems. This leads to the degradation of their productive activities and increases their poverty. We can explain the positive effect of financial inclusion on production by the fact that rural producers rarely see the necessary funds to carry out this activity in accordance with good production standards and this result in low yields at the farm level. Financial services are therefore a way to overcome these shortcomings and ensure a better return on agricultural production. Hence, financial inclusion positively and significantly influences agricultural performance. Thus, the hypothesis that financial inclusion is associated with high-level agricultural performance is validated.

Table 2. Financial Inclusion and Agricultural Performance

Variables	OLS	MLM
	Dependent Variable: Agricultural Performance	
Inclusion financière (1= Dépôts et transfert argent, 0 autrement)	-0.082*** (-3.46)	0.759*** (3.07)
Farmer makes used of fertilizer in production	-0.017*** (-3.45)	0.201*** (6.37)
Size of the Farm	-0.059** (-2.29)	0.985*** (5.33)
Form_agri	0.020 (0.57)	-0.377 (-1.36)
Taille_me	-0.213*** (-5.86)	-0.399 (1.39)
Stama	-0.000 (-0.54)	0.006* (1.69)
Age	0.044 (1.34)	1.887*** (7.39)
Level of Education of the farmer	-0.157*** (-6.24)	0.530*** (2.68)
Sexe of the Farm	-0.101*** (-11.28)	0.115* (1.78)
Intercept	-0.116** (-2.55)	-4.328*** (-18.78)
R-squared/Pseudo R-square	0.5971	0.0256
F-stats/Khi deux	38.462(17; 0.000)	90.541 [18; 0.0000]
Total	120	120

N/B: OLS = Ordinary Least Square; MLM = Multinomial Logit Model
Notes: ***, ** and * indicate 1%, 5% and 10% levels of significance. B / W: Dependent variable is Agricultural Performance; absolute value of robust statistics in parentheses beneath estimates.

The use of chemicals is a positive coefficient, significant at 1%, it should be noted that the probability for a farmer using chemicals to increase his production is greater than that of a farmer. not using 0.201 chemicals. It can be said that the use of chemicals increases the probability of increasing production by 20.1 percent. This result is in agreement with that of Aguera [4], Ashcroft [1] also shows that intensive and appropriate used of chemical fertilizers provide better yields. The reason is that, chemical fertilizers are necessary for the fertilization of the grounds they bring nutrients to the plants which need them for their growth and their development that allows a good growth of the plant which results in a high production. The size of the cultivated area has a positive coefficient of 98.5 percent and significant at 1%. Thus, when the cultivated area increases by a meter square, the probability of increasing production rises by 98.5 percent.

This result is contrary to that of Sen who observes an inverse relationship between farm size and production per hectare in Indian agriculture, and thus suggests that small farms are more productive compared to larger ones. On the other hand, this result is similar to the findings of Claessens [26] who also observed that larger farms obtain higher yields per hectare. Marital status is positively influencing agricultural performance and is significant at 10%. Age has a positive coefficient (1,887) and significant at 1%, this means that when a farmer age increases by one year; the probability to produced increases by 1.887 percent. This result is different from Beck and Patrick [27] who found that increasing age leads to a decrease in physical strength that negatively affects yields.

Level of education has a positive coefficient (0.530) and is significant at 1%. Thus, the probability of a farmer who has studied is higher in increasing production than otherwise. This result is similar to those of Claessens [26], who found that a high level of education contributes significantly to increase agricultural production. On the other hand, this result differs from that of Rios and Shively (2005) who found that a high level of education in small farms leads to a decrease in their production. For them, education increases nonagricultural work opportunities and consequently reduces the intensity of farm management, thus negatively affecting the production of small farms. Gender is significant at 10% and has a positive influence (0.115) on agricultural performance.

Determination of Agricultural Constraints faced by Mbankomo Producers

From Table 3, we see that a large part of the producers (20.8%) face the problems of inadequate improved seed of about 17.5% of producers who think that the poor condition of the roads and the lack of market are constraints to their activity. From this same table, it appears that 15% of the producers noted that the bad condition of the roads, the lack of market and the lack of the improved seeds are the constraints which they face. About 14.2% lack the market outlet and improved seeds, principally, 9.2% noted poor condition of the roads and the lack of improved seeds are the main constraints and finally 8.3% think that the poor state of the road is a production constraint.

Table 3. Determination of agricultural constraints faced by Mbankomo producers

	Frequency	Percent	Valid percent	Cumulative %
Poor road infrastructure	10	8.3	8.3	8.3
Absence of Actual markets	18	15.0	15.0	23.3
Inadequate ameliorated seeds	25	20.8	20.8	44.2
Absence of good road	21	17.5	17.5	61.7
Absent of road and seeds	11	9.2	9.2	70.8
Absence of markets and seeds	17	14.2	14.2	85.0
No roads, no markets and no seeds	18	15.0	15.0	100.0
Total	**120**	**100.0**	**100.0**	

These results are similar to those of Beck and Patrick [27] who found that in many countries, particularly developing ones, family farms have for a long time been confronted with structural difficulties in terms of permanent access to indispensable resources such as land, water, seeds, infrastructure and basic tools.

4. Conclusion

The main objective of this study was to evaluate the contribution of financial inclusion on the agricultural performance of small producers in the municipality of Mbankomo. Specifically, the aim was to establish the socio-economic characteristics of the actors operating in the agricultural sector in Mbankomo, to identify the different financial services available to agricultural actors in the area, to evaluate the effect of the use financial services on agricultural performance and to determine the agricultural constraints faced by Mbankomo producers. In order to achieve this objective, data collected from 120 farmers were analyzed in the SPSS software.

This study shows that the population of the surveyed producers consists largely of men or 51.7% against a minority of women (48.3%). 44.2% of farmers are older than 50 years; the youngest, under 35 represent 3.3% of the sample. The level of education of the respondents is relatively high, 28.3% of the small producers have a primary education, 24.2% of the farmers have a secondary education and only 8.3% have a higher education. The proportion of married farmers is very high (62.5% of the sample) compared to a small number of unmarried farmers (0.8%). It should also be noted that the majority of farmers (40%) have between 5 and 10 people in charge; many farmers exploit between 5,000 and 7500m^2 (40.8%) and a small number exploit 10000m^2 (21.7%); It is found that 76.7% of farmers have never attended training seminars in the agricultural field against 23.3% who have already had to attend. The multinomial logit model was used to achieve the third objective of this study (Evaluating the effect of financial inclusion on agricultural performance). This model proved globally significant and seems good for forecasting purposes.

The different independent variables of the model were previously described. It appears that the probability of an individual making use of deposit and money transfer services to increase production is greater than that of those who do not make use of 0.75; that training in agriculture and household size do not have significant effects on agricultural performance. On the other hand, the variables that significantly influence agricultural performance are: the use of chemicals, marital status, cultivated area, age, level of education, sex, and the variable that interests us most: inclusion financial. It should be noted that all these variables have positive signs. The assumption that comes from this study, states that financial inclusion is associated with high-level agricultural performance; in the light of the above results, this hypothesis is validated. Financial inclusion therefore has a significant and positive impact on agricultural performance in the municipality of Mbankomo.

This study once again highlights the crucial importance of financial services in the agricultural sector in general. In order to improve the production conditions of small farmers, this study recommends: To the public authorities: to strengthen the information dissemination to rural farmers on the usefulness and benefits of the services offered by the MFIs. Take back the financing of agriculture because access to credit has a significant effect on the production of farmers. Also this sector is declared essential by the State to ensure the food security, the poverty reduction and the economic development of the country. This therefore requires the creation of a banking organization dedicated to the agricultural sector. Develop a strategy to encourage financial education so as to draw the attention of the entire population to basic fundamentals of the value of money, the functioning of the financial sector, the knowledge of financial institutions, development of an economic project, the proper use of credit, the use of mobile accounts and types of credit (formal or informal).

We recommend the farmers; to take an interest in the services offered by the MFIs, this first requires the opening of a savings account with these institutions, because affiliation to an EMF has a positive and significant effect on producers' access to credit. To organize itself in OP because it is a mark of credibility in the eyes of the EMF and it positively influences access to credit. Use the funds obtained for productive purposes and not for reasons other than those mentioned in their application for credit in order to be always credible in the eyes of the EMF. To repay their loan on time if they wish to continue to benefit from the services of the EMF because being a good payer is a mark of confidence and credibility. To respect the standards of good production as the financial services are not enough. It also involves the proper use of chemicals and organic products as these fertilizers also have significant and positive effects on productivity. This study has been limited to assessing the contribution of financial inclusion to the agricultural performance of small producers. It would therefore be feasible for future research to analyze the impact of financial inclusion on the standard of living of farmers.

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OPTICAL PROPERTIES OF TIGERNUT (CYPERUS ESCULENTUS) AS INFLUENCED BY MOISTURE CONTENT AND WAVELENGTH

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Abstract

Tigernut (cyperusesculentus) is one among the underutilized crops in Nigeria despite its high economic value. This study investigated the absorbance, transmittance and colour of yellow tigernut as influenced by moisture content at 8%, 16%, 24%, 32% and 42% (db) respectively. The tigernut samples were collected directly from a farm in Minna, Niger state and cleaned to remove all foreign materials, initial moisture content was determined using ASAE standard after which sampleswere conditioned to the desired moisture levels following standard method. Using a spectrophotometer, the absorbance ranged from 3.04 to 6.35 and transmittance ranged from 0.00 to 0.19 within a wavelength range of 320nm to 720nm while the colour using a Chroma meter ranged from 3.73 to 4.14, 5.19 to 8.18 and 13.1 to 19.0 for L (brightness), a (red) and b (yellow) respectively. ANOVA also revealed that moisture has significant effect at $p<0.05$ on absorbance, transmittance and colour of the tigernut. Correlation and regression analysis revealed a positive linear relationship between all moisture contents with absorbance, transmittance and colour.

Keywords

Moisture content, optical properties, absorbance, transmittance, colour and tigernut

1. Introduction

Tigernut (CyperusEsculentus) is a perennial grass-like plant that is cultivated between March and December in Nigeria with spherical tubers of dimension 8mm-16mm as reported by Osagie et al. [1]. It is a pale yellow cream kernel surrounded by a fibrous sheath that have been cultivated for over 400 years ago in both commercial and substantial quantity depending on its demand. According to Obadina et al. [2] tigernut generally is called earth almonds but different people from different countries have different names for tigernut.

In Nigeria, Tigernut is call aya by the Hausa's, akiawusaby the Igbo's and ofioby the Yoruba's. It is cultivated more in the middle belt and northern regions of Nigeria. Tigernut has three varieties classified based on colour, which are Black, Brown and Yellow varieties [3]. According to Okafor et al. [4] and Ebringa [5], the yellow variety is considered the best among the three varieties because of its large size; the fact that more milk can be extracted from it when processed, contains higher protein, has lower fat content and less anti nutritional factors such as polyphenol.

Until recently, there was dearth of information about the potential health benefits of this ancient food tigernut in Nigeria [6]. Tigernuts are edible, sweet, nutty, flavoured tubers that contain protein, carbohydrate, sugars, and lots of oil and fiber [7]. It can be processed into many other edible products. According to Gambo and Da'u [7], tiger nut is one among the best nutritional crops used to augment the diet of humans. Tigernut can be roasted, dried, baked and made into milk recommended for those who have heavy digestion, diarrhea and dysentery because of its high content of digestive enzymes and no lactose or gluten content [8].

Tigernut has 30% of non drying oil which when extracted is cholesterol free and has very low sodium content. It has a composition similar to olive oil and rich mineral contents such as potassium and phosphorus. Tigernut tuber has very high fiber content that makes it very healthy and does not lose its nutritional contents during milling process as reported by Salau et al. [9]. Bamishaiye and Bamishaiye [6] reported that tigernut is an excellent source of minerals such as iron and calcium that are essential for body growth and development. He continues by saying tiger nut can help to prevent heart attacks, thrombosis and activate blood circulation and due to the high contents of soluble glucose, it can help prevent cancer and reduce the risk of suffering colon cancer.

Despite these numerous importance of tigernut as a multipurpose tuber, it has been one among the neglected and underutilized crops in Nigeria because of inadequate knowledge on its production, utilization, nutritional and health value, and non-availability of processing machines as reported by Bamishaiye and Bamishaiye [6].

Tigernut is locally processed without minding the effect on its nutritional quality or value. Developing mechanized processes for harvesting, cleaning, drying, oil or milk extraction, handling and storage facilities for tigernut cannot be successful without an accurate knowledge and availability of itsengineering propertiessuch as physical, mechanical, thermal, optical, electrical properties among others. Studies carried out are majorly on physical properties of tigernut but little has been reported on its mechanical properties while none has been reported for optical

properties. The optical properties are needed in the designing of machines for unit process operations such as sorting, cleaning and grading of tigernut that will monitor and control the quality activities of the tuber and saves human time and labour.

The objective of this study is to determine the absorbance, transmittance and colour of tigernut as influenced by moisture content and wavelength.

2. Materials and Methods

Sample Preparation and Conditioning

The yellow variety of tigernut was purchased from a farm located in Minna Local Government Area of Niger State, Nigeria immediately after harvest and were cleaned and sorted manually and all foreign matter (such as dirt, stones, premature and broken seeds) were removed and stored in a plastic container. The initial moisture contents of the samples was determined to be 7.8%db using the ASAE standard [10] by oven drying the sample at 103°C for 48 hours at the multipurpose central laboratory, university of Ibadan

The sample was divided into five equal weights and conditioned to the desired moisture contents of 8%, 16%, 24%, 32% and 40% (db) each by weighing and adding a calculated amount of distilled water using the Equation 1 below.

$$Q = W_i \left[\frac{M_f - M_i}{100 - M_f}\right] \quad (1)$$

Where; Q is the mass of water to be added in kg, is the initial mass of the sample in kg, is the initial moisture content of the sample in % d.b and is the final moisture content in % d.b

The conditioned samples were stored in airtight polythene and kept in a refrigerator at 5°C for 168 hours (7 days) to ensure uniformity of distributed moisture throughout the samples. The moisture content of the conditioned samples was verified after the seventh day before being used for determining the absorbance, transmittance and colourof the samples.

Determination of Transmittance and Absorbance

A Jenway 6850UV/Vis Spectrophotometer at the food science and technology laboratory, University of Ibadan, was used to determine the transmittance and absorbance of the tuber at various moisture contents with variation of wavelengths within visible light spectra range of 320nm, 420nm, 520nm, 620nm and 720 nm.

Transmittance and absorbance were read directly from the spectrophotometer digital display at different wavelength. The machine was switched on and allowed to warm for 15 minutes after which the sample cell was filled with water and placed inside the cell holder. The blank button was pressed to have zero Absorbance and Transmittance. The sample cell with water was replaced with sample cell filled with samples in the machine. The enter key was pressed to have the absorbance or transmittance value in percentage. The readings were taken in five replicates.

Colour Measurement

Konica Minolta Chroma meter CR-410 was used to give an indicator of colour in the form of L,a,b colour solid values. The L value is an indication of brightness and can be compared to the reflectance information. The amount of red and greenwasindicated by a positive or negative a value, respectively. Similarly, the b value indicates the yellow and bluecolour in the sample with its respective positive or negative number [11]. The readings were taken in five replications.

3. Results and Discussion

Absorbance and Transmittance

The mean values of the absorbance and transmittance are presented on Table 1 and it shows that the absorbance ranged from 3.04 to 6.35 while the transmittance ranged from 0.00 to 0.19.

Table 1. Mean Values of Absorbance and Transmittance of Yellow Tigernut as Influenced by Moisture Content and Wave Length

Moisture level	Wave length	N	Absorbance Mean± Std. Deviation	Transmittance Mean± Std. Deviation
8%	320nm	5	3.13±0.01^{e}	0.00±0.00^{a}
	420nm	5	3.94±0.15^{d}	0.01±0.00^{b}
	520nm	5	3.41±0.03^{c}	0.03±0.01^{c}
	620nm	5	3.18±0.02^{b}	0.05±0.01^{d}
	720nm	5	3.04±0.01^{a}	0.09±0.01^{e}
16%	320nm	5	3.25±0.04^{e}	0.00±0.00^{a}
	420nm	5	4.59±0.15^{d}	0.02±0.00^{b}
	520nm	5	3.57±0.01^{c}	0.04±0.00^{c}
	620nm	5	3.26±0.02^{b}	0.07±0.00^{d}
	720nm	5	3.19±0.02^{a}	0.09±0.00^{e}
24%	320nm	5	3.39±0.00^{e}	0.05±0.01^{a}
	420nm	5	5.025±0.00^{d}	0.06±0.01^{b}
	520nm	5	3.62±0.00^{c}	0.07±0.00^{c}
	620nm	5	3.35±0.00^{b}	0.08±0.01^{d}
	720nm	5	3.23±0.00^{a}	0.10±0.00^{e}
32%	320nm	5	3.52±0.00^{e}	0.060±0.001^{a}
	420nm	5	5.69±0.00^{d}	0.09±0.00^{b}
	520nm	5	3.78±0.04^{c}	0.10±0.01^{c}
	620nm	5	3.45±0.00^{b}	0.09±0.05^{d}
	720nm	5	3.39±0.00^{a}	0.13±0.01^{e}
40%	320nm	5	3.85±0.00^{e}	0.06±0.00^{a}
	420nm	5	6.35±0.00^{d}	0.11±0.00^{b}
	520nm	5	4.02±0.00^{c}	0.13±0.01^{c}
	620nm	5	3.63±0.00^{b}	0.14±0.00^{d}
	720nm	5	3.49±0.01^{a}	0.19±0.01^{e}

The absorbance increased as moisture content increases (Figure 1) but decreased as the wavelength increases (Figure 2) within constant moisture content.ANOVA revealed a significant difference at P<0.05 among the absorbance of the yellow tigernut at different moisture content (Table 2). This result is in line with the reports of Hernandez et al. [12], Fang et al. [13] and Cubeddu et al. [14] in their studies. Absorbanceis the capacity of a substance to absorb light of a specified wavelength. This indicates that the more the water content of tigernut, the more it will absorb light rays and the higher the wavelength of the light ray, the lesser the absorption capacity of tigernut.

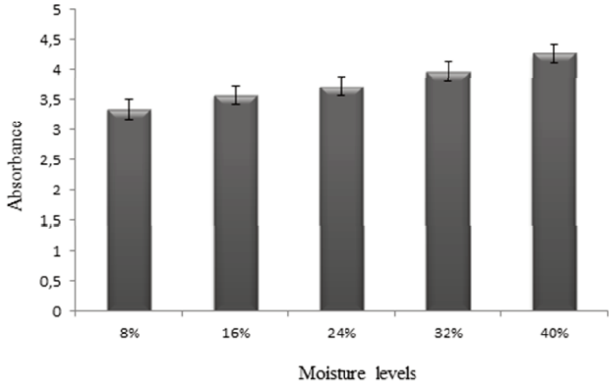

Figure 1. Absorbance trend of tigernut influenced by moisture

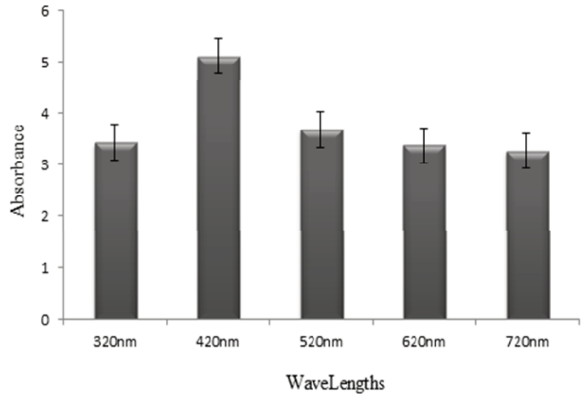

Figure 2. Absorbance trend of tigernut influenced by Wavelength

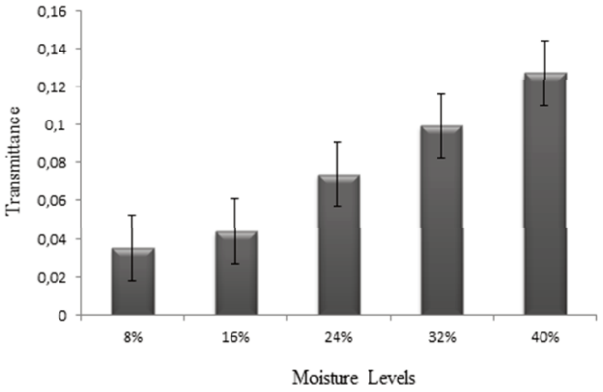

Figure 3. Transmittance trend of yellow tigernut influenced by moisture

Transmittance of the yellow tigernut increased as both the moisture content and wavelength increases(Figures 3 and 4). ANOVA revealed a significant difference at P<0.05 among the transmittance at different moisture content (Table 3). The result is in line with those reported by El-Raieet al.,(2009) and Fang et al. [13] in their research. Transmittance of the surface of a material is its effectiveness in transmitting radiant energy. It is the fraction of incident electromagnetic power transmitted through a sample, in contrast to the transmission coefficient, which is the ratio of the transmitted to the incident electric field.

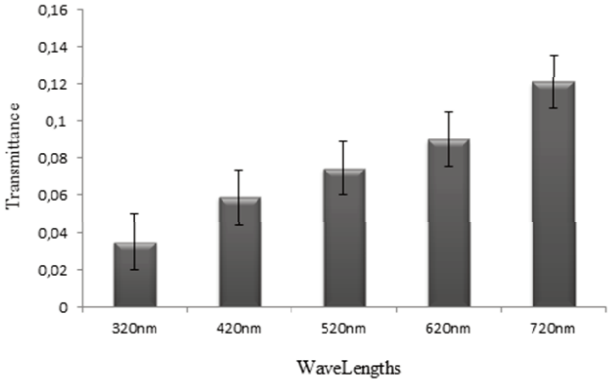

Figure 4. Transmittance trend of yellow tigernut influenced by WaveLength

Table 2. ANOVA Result on absorbance of tigernut at 95% significant level

Dependent Variable: Absorbance					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Moisture level	12.835	4	3.209	1.537E3	0.000*
Wavelength	58.927	4	14.732	7.054E3	0.000*
Moisture level * Wavelength	8.648	16	0.540	258.803	0.000*
Error	0.209	100	0.002		
Total	1860.415	125			
Corrected Total	80.619	124			

*Represents significant difference at P< 0.05

Correlation analysis performed on the Transmittance revealed a stronger positive linear relationship of moisture and wavelength with correlation coefficients(R) of .714 and .605 respectively.

Colour

The tigernut colour as influenced by moisture content was measured using the KonicaMinolta Chroma meter and the mean

values presented on Table 5 revealed that the colour ranged from 3.73 to 4.14, 5.19 to 8.18 and 13.1 to 19.0for L (brightness), a (red) and b (yellow) respectively. These values all increased as the moisture content increases (Figures 5, 6 and 7).

Table 3. ANOVA Result on transmittance of tigernut at 95% significant level

Dependent Variable:Transmittance Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Moisture level	0.142	4	0.035	316.132	0.000*
Wavelength	0.103	4	0.026	229.757	0.000*
Moisture level * Wavelength	0.015	16	0.001	8.351	0.000*
Error	0.011	100	0.000		
Total	0.972	125			
Corrected Total	0.271	124			

* Represents significant difference at P< 0.05

Table 4. Mean Values of Tigernut Colour as Influenced by Moisture Content

Moisture Levels	N	L (Brightness) Mean± Std. D.	a (Red) Mean± Std. D.	b (Yellow) Mean± Std. D.
8%	5	37.3^{a}±.14	5.19^{a}±.02	13.1^{a}±.07
16%	5	38.3^{a}±.15	6.52^{b}±.05	14.7^{b}±.07
24%	5	39.5^{ab}±.28	6.96^{b}±.56	14.8^{b}±.92
32%	5	40.8^{b}±2.81	8.01^{c}±.35	18.4^{c}±1.42
40%	5	41.4^{b}±.35	8.18^{c}±.01	19.0^{c}±.11
Total	25	39.5±1.95	6.97±1.14	16.0±2.45

*Different letters within the same column indicate significant differences according to Duncan's New Multiple Range Test (p<0.05).

Table 5: ANOVA Result on colour of tigernut at 95% significant level

		Sum of Squares	Df	Mean Square	F	Sig.
L(Brightness)	Between Groups	58.945	4	14.736	9.074	0.000*
	Within Groups	32.482	20	1.624		
	Total	91.427	24			
a (Red)	Between Groups	29.625	4	7.406	84.528	0.000*
	Within Groups	1.752	20	0.088		
	Total	31.378	24			
b (Yellow)	Between Groups	132.424	4	33.106	57.282	0.000*
	Within Groups	11.559	20	0.578		
	Total	143.983	24			

* Represents significant difference at P< 0.05

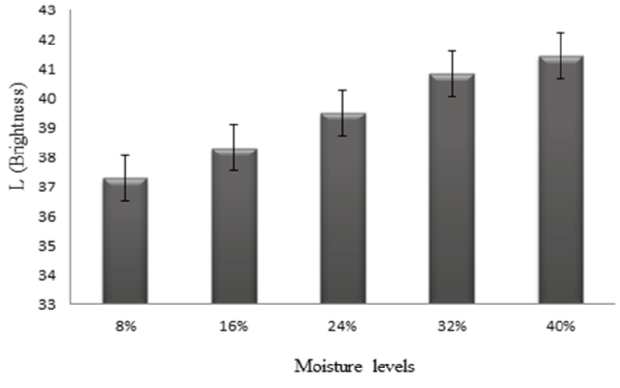

Figure 5: L (Brightness) trend

ANOVA, Regression and Correlation Analysis of colour

ANOVA revealed a significant difference at P<0.05 among the L, a and b of the yellow tigernut at different moisture content shown on table 4.Regression and correlation was carried out on the L, a and b values and it revealed that there is a positive linear relationship between moisture content and the L, a and b colour values and the L, a and b as a function ofmoisture content can be expressedusing the following linear regression equations;

L=36.231+1.080M with R=.796 and R^2= .638

a=4.728+0.747M with R =.943 and R^2 =.890

b=11.342–.552M with R=.915 and R^2=.837

Where L= Brightness, a=Red, b=Yellow and M=Moisture content.

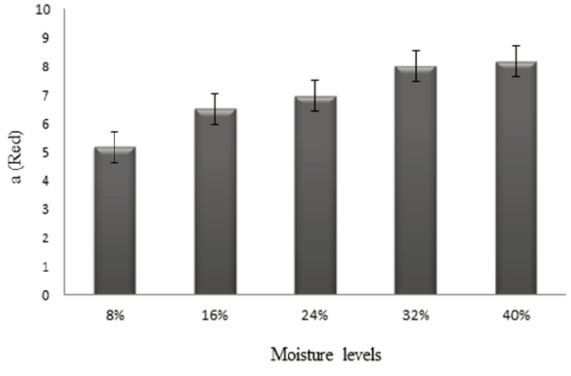

Figure 6: a(Red) trend

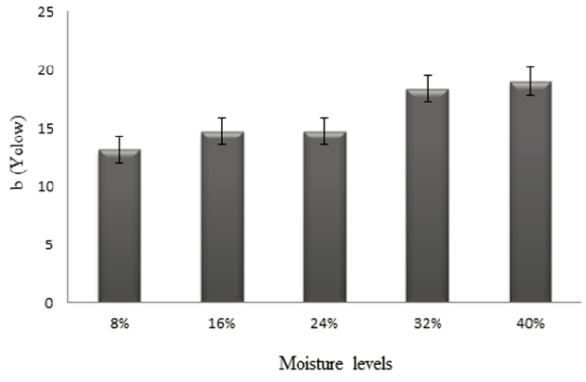

Figure 7: b(Yellow) trend

4. Conclusion

This study investigated the absorbance, transmittance and colour of yellow tigernut (cyperus esculentus) as affected by moisture content and based onthe results obtained,Moisture content and wavelength have significant influence at $P<0.05$ on the absorbance, transmittance and colour of yellow tigernut. The moisture and wavelength has a poor positive linear relationship with absorbance and a stronger positive linear relationship with transmittance and colour (Lab).

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EFFECT OF SELECTED HOE TYPES AND FORWARD SPEED ON THE PERFORMANCE OF A DEVELOPED MECHANICAL ROW CROP WEEDER

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Abstract

A mechanical row crop weeder was developed to overcome the tedious manual weeding operation experienced in a row crop farming system and its performance evaluated. The machine is made up of a frame, handle, hoeing disk, pneumatic wheel, belt/pulley and power unit. Three different weeding tool types (U-blade, L-blade and Hoe-blade) were developed and used at three different walking speeds of 0.2, 0.4, and 0.6 m/s in three replications. The experimental plots were 27 which measured 800cm by 26cm each. Parameters such as weeding efficiency, weeding index, Field efficiency, effective field capacity and theoretical field capacity were measured using standard known formulae. This weeding machine has a swath-width of cut of 26cm which corresponds to an average furrow width of farm cropping system. Results from field performance showed that both theoretical and effective field capacities increased with increase in the walking speed of the operator while field efficiency decrease with increase in the walking speed. The mean field efficiencies obtained were 93.58 %, 91.91 % and 85.64 % at the walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively. ANOVA revealed that the working speed and tool type have significant effect on the weeding index and weeding efficiency of the machine at $p<0.05$. The results showed that weeding index decreased with increasing walking speeds with all the tool types investigated, the walking speed of 0.2 m/s had the highest weeding index of 0.937 with the L-blade tool type. The least weeding index of 0.580 was obtained at the walking speed of 0.6 m/s with the hoe-blade tool type. The highest weeding efficiency of 93.7 % was obtained for 0.2 m/s walking speed and L-blade tool type. This device will contribute greatly to weeding status of row crop farms for small scale farmers

Keywords

Hoe, speed, performance, row, crop and weeder

1. Introduction

Weed is essentially any plant growing in the wrong place at the wrong time and doing more harm than good [1]. Among the activities involved in crop production such as land preparation, weeding, fertilizer application and harvesting, weeding is the most labour-intensive operation [1]. Weeding accounts for about 25% of the total labour requirement (900-1200 man-hours/hectare) during a cultivation season [2].

The use of sort handle hoe is effective and it is the most widely used manual weed control method in Nigeria. It is reported that manual weeding is labour-intensive, accounting for about 80% of the total labour required for producing food in Nigeria [3]. [4] observed that a farmer using only hand hoe for weeding would find it difficult to escape poverty, since this level of technology tends to perpetuate human drudgery, risk and mystery. [5] concluded that the use of herbicides has possible effect on desert encroachment and other adverse impact, while [6] asserted that the need for non-chemical weed control techniques has steadily increased in the last fifteen years, as a consequence of the environmental pollution originated by the intensive application of pesticides in agriculture. The use of herbicides in killing weeds has been the usual practice of some farmers but the recent upsurge in environmental awareness of the public and interest in organic food production and some health related problems with the use of herbicides not to be a better alternative.

The most common methods of weed control are mechanical, chemical, biological and cultural methods. Out of these four methods, mechanical weeding either by hand tools or weeders are most effective in both dry land and wet land [7]. Various types of cutting blades are used for manually operated weeders. V-shaped sweep is preferred where weeders are continuously pushed and tool geometry of these cutting blades is based on soil-tool-plant interaction [8]. Mechanical weed control don't only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity. Manual weeding can give a clean weeding but it is a slow process [9].

As the time period available for weeding is limited, improved mechanical weeders are to be used to complete the weeding operation in due time at less cost. At present, there are different designs of hoes and weeders available in Nigeria. All these designs are region specific to meet the requirements of soil type, crop grown, cropping pattern and availability of local resources.

The use of herbicides in killing weeds has been the usual practice of some farmers but the recent upsurge in environmental awareness of the public and interest in organic food production and some health related problems with the use of herbicides not

to be a better alternative. [10] reported that mechanical weed control allows farmers to reduce or even eliminate herbicide use. He gave a comparison of mechanical weeding versus herbicides use and concluded that mechanical weeding reduces cost of weed control, aerates the soil, reduces pollution, breaks soil crust and contributes to a better environment. Thus, there is a need for the design and development of a mechanical weeder for intensive and commercial farming system in Nigeria.

The objective of the project is to design and construct a mechanical weeder, evaluate three deferent weeding blades and the performance of the machine.

2. Materials and Methods

Description of the Machine

Figures 1 and 2 are the isometric and orthographic drawings of the row crop weeder. The principal components of the machine are the frame, handle, hoeing disk, power and transmission unit. The weeder is powered by a two stroke petrol engine. The belt and pulley mechanism actuate and power is transmitted to the shaft which rotates the weeding implement through the bearing that is mounted on a frame. A slight push by the operator moves the machine in the direction for which weeding is required.

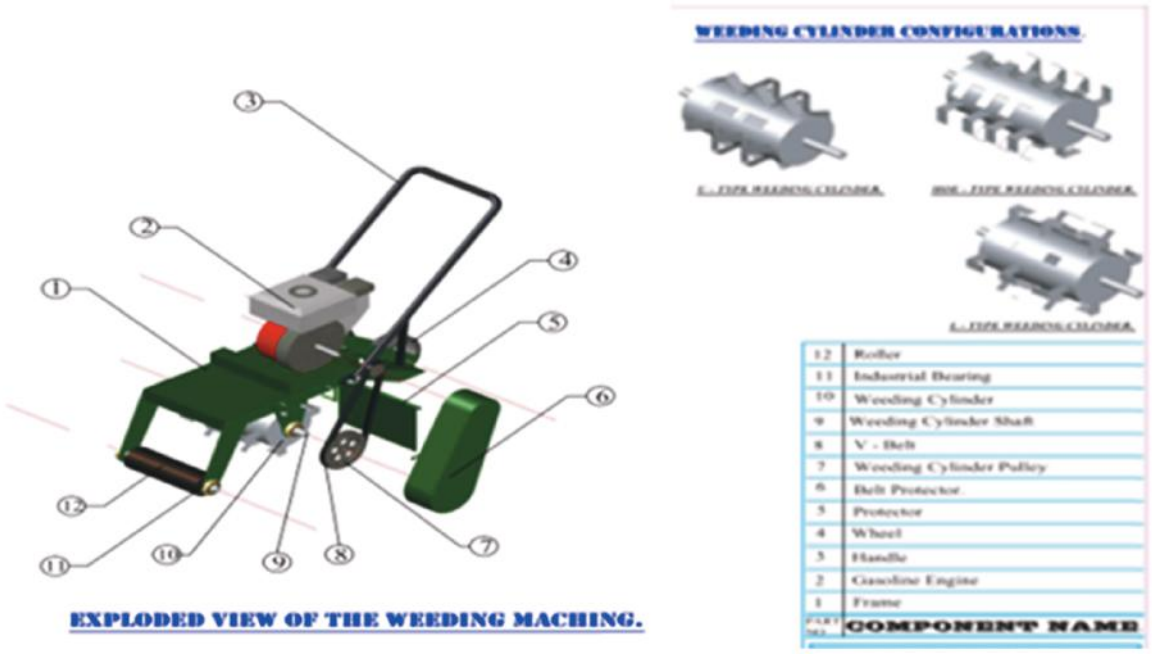

Figure 1. Isometric Drawing of the Row Crop Weeder

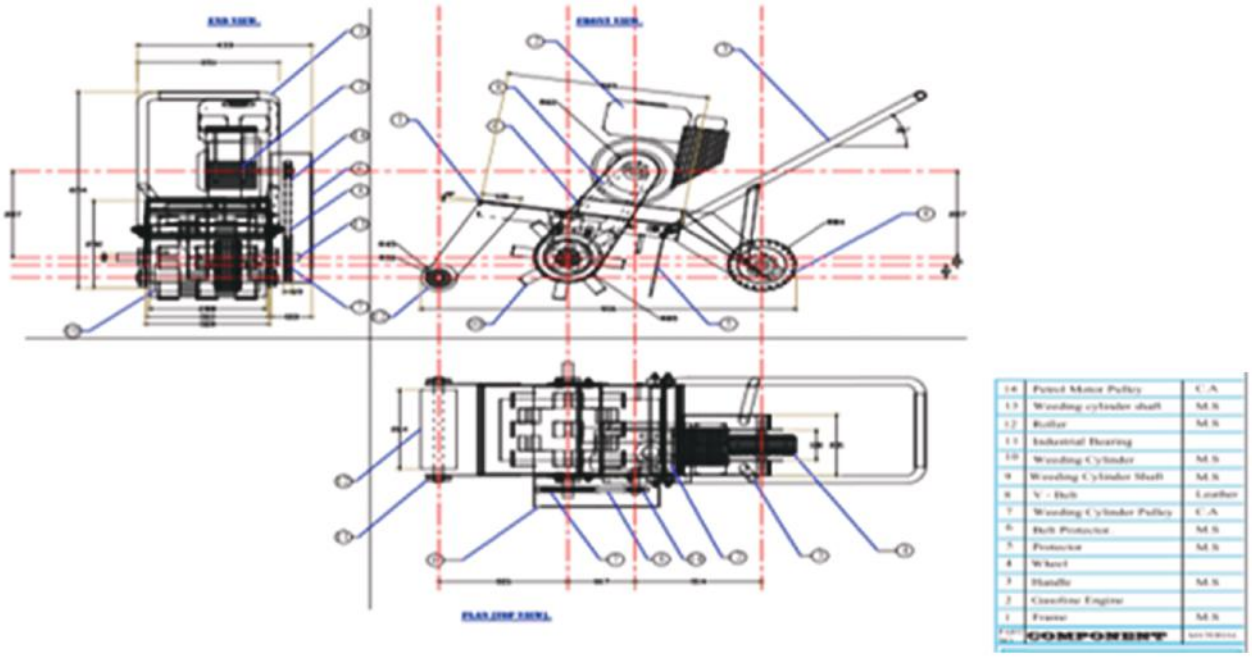

Figure 2. Orthographic drawing of the row crop weeder

Machine Performance Evaluation

Effective Field Capacity

Effective field capacity is the amount of area that a weeding tool can cover per unit time. It was determined using Equation 1.

$$E_{fc} = T_w + T_t + T_r \quad (1)$$

Where:
E_{fc}= Effective field capacity (ha/hr),
T_w = Time taken for weeding (hr),
T_t = Time taken for turning (hr),
T_r = Time taken for resting (hr).

Theoretical Field Capacity

This is the rate of field coverage, if the machine works all the time at recommended speed and utilizes its entire width of operation. The theoretical filed capacity was determined using 0.2, 0.4 and 0.6 m/s respectively by applying Equation 2 below.

$$T_{fc} = T_w \quad (2)$$

Where:
T_{fc} = Effective field capacity (ha/hr),
T_w = Actual time taken for weeding (hr).

Field Efficiency

Field efficiency is the ratio of the effective field capacity to the theoretical field capacity which was calculated using Equation 3

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoritical field capacity}} \times 100\ \% \quad (3)$$

Weeding Index

Weeding index is a ratio between the number of weeds removed by a weeder and the number present in a unit area and is expressed as a percentage and was calculated using Equation 4.

$$IW = \frac{W_1}{W_1+W_2} = \frac{W_1}{W_1+(W_T-W_1)} \quad (4)$$

Where,
IW = weeding index,
W_1 = weight of weeds removed (g),
W_2 = weight of survived weeds (g),
W_T = Total weight of weeds (g)

Weeding Efficiency

Weeding Efficiency was calculated using Equation 5.
Where,

$$E_w = \frac{W_1}{W_1+W_2} \times 100\% = \frac{W_1}{W_1+(W_T-W_1)} \times 100\% \quad (5)$$

E_w = weeding efficiency (%),
W_1 = weight of weeds removed (g),
W_2 = weight of survived weeds (g) and
W_T = Total weight of weeds (g)

Experimental Plot Design

The experimental plot is located beside the collapsed mini dam at theUniversity of Agriculture, Makurdi road (Figure 1). The experimental plot was measured out using a measuring tape. Its dimensions were 8 m long and 7 m wide. The experiment was laid out in a Completely Randomized Design (CRD).

Figure 3. The Experimental Field

The experimental design for the statistical analysis follows a two-treatment effect (walking speed and tool type) in a split-plot factorial design with Completely Randomized Design (CRD) involving a two-way classification with three observations (replications) per experimental unit. The experimental unit comprises two factors; three walking speeds (0.2, 0.4 and 0.6 m/s) in each of the three tool types(U-type cutting blade, L-type cutting blade and Hoe type cutting blade) giving nine treatment

combinations and twenty-seven observations for the experiment as walking speed versus tool type. The walking speed in the combination forms the levels of factor 'A' while the tool type forms the levels of factor 'B'. All data collected were subjected to analysis of variance (ANOVA) to test for significant effects at 95 % confidence limit using the procedure recommended [11]. When significant difference was observed, treatment means were separated using the F-LSD.

3. Results and Discussion

The raw and mean results of the weight of weeded and total weight of weeds, weeding index, weeding efficiency and time of weeding are presented in Table 1, 2, 3 and 4 respectively.

Table 1. Raw and Mean values of the Weight of Weeded and Total weight of Weed for the Various Hoe-Types at Different Walking Speeds

Tool Type	Rep	Working Speed (m/s)					
		0.2		0.4		0.6	
		Weight removed, kg	Total weight, kg	Weight removed, kg	Total weight, kg	Weight removed, kg	Total weight, kg
U-blade	1	0.39	0.45	0.25	0.37	0.32	0.50
	2	0.51	0.56	0.38	0.54	0.35	0.60
	3	0.34	0.40	0.28	0.42	0.36	0.57
	Mean	0.41	0.47	0.30	0.44	0.34	0.56
L-blade	1	0.44	0.48	0.38	0.46	0.37	0.49
	2	0.47	0.50	0.29	0.38	0.39	0.53
	3	0.42	0.44	0.37	0.45	0.30	0.40
	Mean	0.44	0.47	0.35	0.43	0.35	0.47
Hoe blade	1	0.38	0.51	0.30	0.48	0.22	0.42
	2	0.41	0.54	0.36	0.52	0.30	0.44
	3	0.42	0.53	0.35	0.55	0.23	0.43
	Mean	0.40	0.53	0.34	0.52	0.25	0.43

Table 2. Raw and Mean Values of the Weeding Index of the Selected Hoe Types at the Different Walking Speeds

Tool Type	Replications	Working Speed (m/s)		
		0.2 Kg	0.4 Kg	0.6 Kg
U – Blade	1	0.867	0.676	0.640
	2	0.911	0.704	0.583
	3	0.850	0.667	0.632
	Mean	0.876	0.682	0.618
L – Blade	1	0.917	0.826	0.755
	2	0.940	0.763	0.736
	3	0.955	0.822	0.750
	Mean	0.937	0.804	0.747
Hoe Blade	1	0.745	0.625	0.524
	2	0.759	0.692	0.682
	3	0.792	0.636	0.535
	Mean	0.765	0.651	0.580

Table 3. Raw and Mean Values of the Weeding efficiency of the Selected Hoe Types at Different Walking Speeds

Tool Type	Replications	Working Speed (m/s)		
		0.2	0.4	0.6
U – Blade	1	86.7	67.6	64.0
	2	91.1	70.4	58.3
	3	85.0	66.7	63.2
	Mean	87.6	68.2	61.8
L – Blade	1	91.7	82.6	75.5
	2	94.0	76.3	73.6
	3	95.5	82.2	75.0
	Mean	93.7	80.4	74.7
Hoe Blade	1	74.5	62.5	52.4
	2	75.9	69.2	68.2
	3	79.2	63.6	53.5
	Mean	76.5	65.1	58.0

Table 4. Time of Weeding

Speed (m/s)	weeding (s)	Turn (s)	Total (s)
0.2	40	3	43
0.4	20	2	22
0.6	13	2	15
Mean	24.33	2.33	26.67

Table 5. Mechanical Row Crop WeederPerformance Evaluation

Speed (m/s)	Effective field capacity (ha/hr)	Theoretical field capacity (ha/hr)	Field efficiency (%)
0.2	0.0175	0.0187	93.58
0.4	0.0341	0.0371	91.91
0.6	0.0495	0.0578	85.64
Mean	0.0337	0.0379	90.38

Table 6. ANOVA Result on Weeding Index

Sources of Variation	Df	SS	MS	Observed F	Required F (5%)
Working Speed (S)	2	0.2108	0.1054	70.27*	3.55
Tool Type (T)	2	0.1236	0.0618	41.20*	3.55
Interaction (S×T)	4	0.1236	0.0309	20.60*	2.93
Error	18	0.0273	0.0015		
Total	26	0.3685			

* Represent significant difference

Table 7. ANOVA Result on Weeding Efficiency

Sources of Variation	Df	SS	MS	Observed F	Required F (5%)
Working Speed (S)	2	2107.89	1053.945	69.34*	3.55
Tool Type (T)	2	1235.79	617.895	40.65*	3.55
Interaction (S×T)	4	1235.79	308.948	20.33*	2.93
Error	18	273.58	15.199		
Total	26	3685.27			

* Represent significant difference

4. Discussion

To carry out the evaluation, the performance of the constructed weeder was conducted on the experimental field to investigate the effect of walking speeds and blade types on performance of the weeding tool.The weeder was tested on a flat wet ground surface with average weeds density. Three different weeding tool types (U-blade, L-blade and Hoe-blade) were used with three different walking speeds of 0.2, 0.4, and 0.6 m/s. Each of the experiments was repeated thrice at 800cm length run at constant weeding width of 26 cm giving an area of 20,800 cm2 (2.08 m2).

A time study was carried out to obtain the capacity performance of the weeder during the weeding operation. The observations were obtained for each operations and the average for the speed, turning, machine failure, management stop and the operation time as well as the total field time were obtained for each weeding operation. During the time study, the 8 m length plot was cover in 40 seconds, 20 seconds and 13 seconds at different walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively.

Soil Properties

The soil properties investigated include soil texture, soil particle size distribution, moisture content, bulk density, soil porosity and soil strength. The result of soil texture shows that the soil of the experimental plot is predominantly sandy. The mean percentage sand is 87.8% compared to silt and clay which are 4.3 % and 7.8 % respectively. The mean particle size distribution was 16.6 % and 83.4 % for silt/clay and sand respectively. The sandy nature of the experimental plot therefore, is ideal for tillage and weeding operations. Soils that are predominantly sand are classified as coarse texture soils according to [12] co-operate documents. According to [3], the predominant soil type in Makurdi is sandstones. On soil texture, [12] reported that soils that have high sand contents are easy to cultivate, plant and harvest which are termed to be light whereas soils that are difficult to cultivate, plant and harvest have high clay content and are called heavy soils.

The percentages of soil moisture content obtained immediately before planning at five randomly selected places at a depth of 5

cm ranged from 10.6 % to 11.8 % with a mean of 11.34 %. The soil moisture content greatly affects weeding operations. Dry soils are difficult for most weeding tool penetration and increased draft. If the soil becomes extremely dry, it is extremely difficult for the soil cutting tool to penetrate. Soil moisture content has considerable influence on the soil shear strength and the resistance of the soil to sliding at an interface and scouring ability of weeding blades.

The result of bulk density on the experimental plot before weeding operations has mean result of 1.445 kg/m3. This indicates that the bulk density of 1.455 kg/m3 observed in the soil makes weeding easy. It was also observed that porosity ranged from 31.14 % to 49.10 % with the mean value of 40.82 %.

The minimum value of the soil strength was 64.27 N/m2 and the maximum value was 64.27 N/m2, with the mean value of 65.72 N/m2. This shows that the soil shear strength for penetration and weeding will be easy.

Capacity Performance of the Weeder

A time study was carried out to obtain the capacitive performance of the harvesting operation. The observations were obtained for each operation and their average for the speed, turning, machine failure, management stop and the operation times as well as the total field time were obtained for each weeding operation.

From Table 5, it was observed that both the theoretical and effective field capacities increased with increase in the walking speed of the operator. It was also observed that the field efficiency has negative association with the walking speed of the operator. The field efficiency decreases with increase in the walking speed. It was observed that the average effective field capacities were 0.0175 ha/hr, 0.0341 ha/hr and 0.0495 ha/hr at the walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively while the average theoretical field capacities were found to be 0.0187 ha/hr, 0.0371 ha/hr and 0.0578 ha/hr at the walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively and the field efficiencies obtain were 93.58 %, 91.91 % and 85.64 % at the walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively.

Effect of walking speed and tool type on the weeding index

From the ANOVA result (Table 6), there is a significant effect of the walking speed,] and tool type on the weeding index of the weeding machine. It was observed that the weeding index decreased with increasing walking speeds with all the tool types investigated. The walking speed of 0.2 m/s had the highest weeding index of 0.937with the L-blade tool type. The least weeding index of 0.580 was obtained at the walking speed of 0.6 m/s with the hoe-blade tool type.

Effect of walking speed and tool type on the weeding efficiency

From the ANOVA result (Table 7), there was a significant effect of the walking speed and tool type on the weeding efficiency of the machine. It was observed that the weeding efficiency decreased with increasing walking speeds with all the tool types investigated. The best weeding efficiency of 93.7 % was obtained for 0.2 m/s walking speed and L-blade tool type. The lowest weeding efficiency of 58.0 % was obtained for the condition of 0.6 m/s and hoe-blade tool type.

5. Conclusion

The presented research can be concluded as follows:

- That a mechanical row crop weeding machine was designed, fabricated and evaluated successfully. The L-type blade gave the best performance among the three blade types used.
- The highest weeding efficiency of 93.7% was obtained at a walking speed of 0.2m/s. with the L-type blade.
- The theoretical and effective field capacities increased with increase in the walking speed of the operator while the field efficiency decreased with increase in the walking speed.
- ANOVA result revealed there was a significant effect on the walking speed and tool type on the weeding index and efficiency of the developed weeding machine.

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IMPROVING THE WEARING PROPERTIES ON BIOGAS PLANT SHREDDING MA-CHINE

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Abstract

Using biomass for energeticis the most environment friendly and the best ecological solution to generate biogas. In agricultural environment generally use the primer biomass, and second-ary (from livestock) biomass is used for generate biogas. The technology mostly use primer materials, like parts of plants, rest of seeds. These materials make stable the biogas plant. The ingredients are nearly the same across the product year. Input materials for fermentation are quite variable. These materials influence the method for preparation. Solid materials as inputs for fermentors necessary to make smaller parts by shredding machine.

Keywords

economy, energy production, biogas, modern technology

Introduction

The NHSZ Biogas Tatabanya Ltd. biogas plant use mixed materials to generate biogas. The most important part of the technology is the preparation of the fiber (mainly corn) for shredding [1]. In our tests we used BHS Biorinder RBG 08 type solid material mincing machine was applied. The machine shredding prorepties wasn't compliance at case of different input solid material. The fermentors vane usually was covered long fiber materials. That event make bad effect for mixing and fermentation process. On other hand the parts of the machine had intense changing period, because of the intensive wearing effect. Figure 1 shows the BHS Biogrinder RBG 08.

The technical suggestions were at the following areas [2]:

- hard metal technology to avoid the intensive wearing
- the mentioned wearing parts hardened by hard metal technology
- operational test for long distance application ability
- economical analysis for return of investment.

The structure of the grinding unit

The biomass grinding is made by turning hammers [3]. One machine is able to get 12 hammers. The material flow is supported by standing part, it is working like a standing knife. The turning parts are demonstrated in Figure 2 and 3.

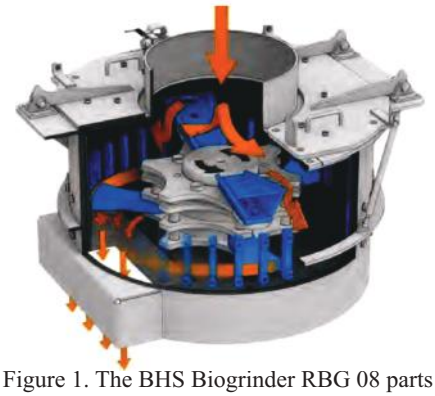

Figure 1. The BHS Biogrinder RBG 08 parts

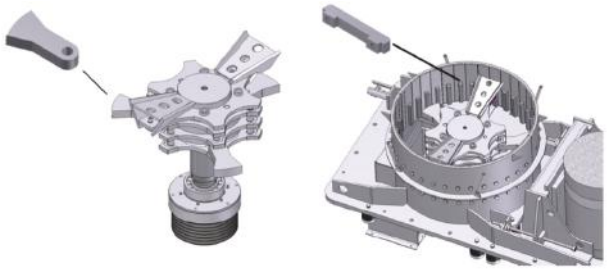

Figure 2. The BHS Biogrinder RBG 08 machine turning and fix parts

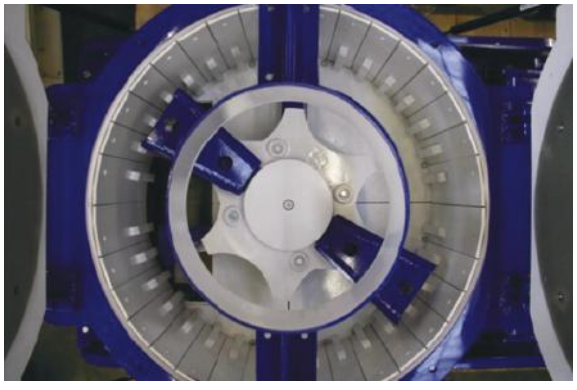

Figure 3. The turning and fix parts view from top

The Wearing

The parts of the machine what are touched by moving materials are wearing caused by the friction. The input materials used for biogas generating creating wearing, and the hammers form is changing. Different input materials have different effect on the wearing. The most intensive wearing made by sand dust from manure. The rest of soil moved by the animals' leg.

This effect is typical on animal farms. The tested plant is a real source of danger, because the sand rate of the manure is high. Because of the wearing fix part and moving hammer have bigger distance, the shredding efficiency get worse. Figure 4 and 5 show the difference be-tween the original and used hammer.

Figure 4. Distance between fix part and hammer, original (operational photo)

Figure 5. Distance with used hammer (operational photo)

Figure 6. Manure from straw, before and after

Based on institute (Institut für Landtechnik und Tierhaltung, Weihenstephan, Freising) meas-urement we mentioned that the structure of manure from straw not changed using hammered shredding (Figure 6). This type of machine is not applicable for this type of materials.

Figure 7. Worn hammer

Figure 7, 8 and 9 show the worn hammer and its implemented and stand-alone forms. The form changing is too big for normal usage.

Figure 8. Used hammer

Figure 9. Unmounted used hammer

Improvement by hard metal welding

Technologies for improving wear resistance:

– hard metal scattering is electric scattering
– hot metal spraying
– pottery reading
– application of porous ceramic
– abrasion resistant plastic spray
– manufacture of abrasion-resistant inserts, lining and parts
– spark welding

– heat treatment
– surface treatment

At the Szent István University Mechanical Engineering Faculty we made hard metal welding.

For testing 3 hammer was prepared 3 different welding:

1) The (-) signed hammer, the suture was parallel with the axle.
2) The (/) signed hammer the suture was at 45° by the axle, at the same distance
3) The (X) signed hammer the suture was at 45° by the axle but the oppsite direction as / signed hammers. Sutures are at the same distance.

Scattering is good for improve working period, and the optimal material usage also important. Figure 10 shows the hammers.

Table 1. shows the technical parameters of the welding technology

Figure 10. Hard metal welded hammers

Table 1. The technical parameters of the welding technology

Sign	Standard	Chemical (%)	Current
502	DIN 8555: E 10-GF-60 GR	C: 5,50 Mn: 1,50 Cr: 40,0 Other: 2	= +160 A

Wearing test

The shredder was used at normal working conditions (Figure 11). After 600 working hours the wearing was too big for normal conditions. we checked the parts by eyes. We diagnosed that there is no dangerous anomaly (broken parts, deformation, other structural injury).

Figure 11. After 600 working hour, with hard metal welding

Figure 12, 13 and 14 show the hammers. As the pictures shows there is no injury on the hammers. The signs are for identification.

Figure 12. Hammers, side view

Figure 13. Hammers, top view

Figure 14. Hammers, button view

2. Material and Method

We use 3D scanning to measure the wearing size. The 3D scanner is a ZScanner 700 machine.

The 3D scanning method [4,5]:

- define joints, surface net
- elementary body unit calculation
- surface units summary

The scan results of the worn hammer are shown in Figure 15.

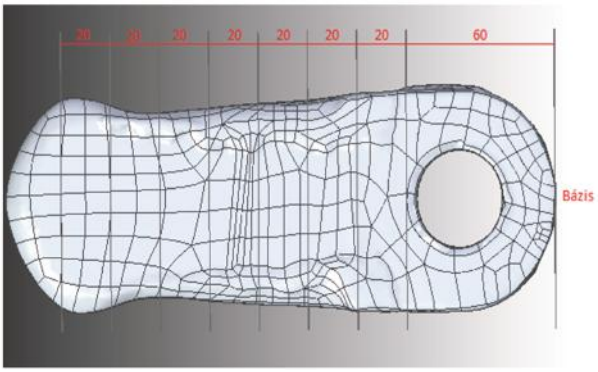

Figure 15. Scanned worn hammer

3. Results

Table 2 shows the results for (/) hammer. This has the minimal size changing 83,5% based on the original size. The most worn hammer is the (-) signed.

Table 2. Size changing

Size (long)		
[mm]		
(x) worn	**(-) worn**	**(/) worn**
219	218	222
(x) new	**(-) new**	**(/) new**
267	266	266
rate		
(x)	**(-)**	**(/)**
0,820	0,820	0,835

Table 3 shows the width changing by the different parts.

We calculated the wear by the weight of the hammers. Weight is calculated from the volume of the original and worn hammers (Table 4).

Table 4. Volume and weight changing

	Volume [mm^3] new		
	(X)	**(-)**	**(/)**
	1056435	1066941	1047621
	Volume [mm^3] weared		
	(X) weared	**(-) weared**	**(/) weared**
	357603	333335	358062
Volume rate:	0,338	0,312	0,342

	Weight [g] weared		
	(x) weared	**(-)weared**	**(/)weared**
	2750	2550	2760
	Weight [g] new		
	(x)	**(-)**	**(/)**
	8124,08	8162,06	8075,23
Weight rate:	0,338	0,312	0,342

	(X)	**(-)**	**(/)**
	1056435	1066941	1047621
	Volume [mm^3] weared		
	(X) weared	**(-) weared**	**(/) weared**
	357603	333335	358062
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	Weight [g] weared		
	(x) weared	**(-)weared**	**(/)weared**
	2750	2550	2760
	Weight [g] new		
	(x)	**(-)**	**(/)**
	8124,08	8162,06	8075,23
Weight rate:	0,338	0,312	0,342

Conclusion

Based on the operational tests we diagnose that the hard metal welded hammers make more effective and economical operating. Optimal solution based on suture is the (/) signed hammer. Based on our measurement we recommend that structure. Our test shows that the button part is worn more. Because of this, we recommend the whole button part should be covered by hard metal.

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EFFECT OF MICROWAVE ASSISTED ALKALI AND ACIDIC PRE-TREATMENT ON THE BIODEGRADABILITY OF DAIRY SLUDGE

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Abstract

Advantageous effects of microwave pre-treatment on biodegradability of different kind of wastewater sludge have been verified in many papers. Chemical pre-tretments are also suitable to increase the disintegration degree and to enhance the biogas production from sludge. Combination of microwave irradiation with chemical methods could be a promising pre-treatment process for enhanced biodegradability. Combined microwave-alkaline pre-treatment methods are more commonly used for sludge pre-treatments than microwave-acidic method. Therefore, our aim was to investigate the effect of microwave assisted alkali and acidic pre-treatment on organic matter release from sludge and biodegradability. Our results verified that beside microwave-alkaline pre-treatment methods, the microwave-acidic process is suitable as potential pre-treatment method, but particularly is capable for enhanced aerobic biodegradability of dairy sludge.

Keywords

microwave, sludge, biodegradability, pre-treatments

1. Introduction

Attention to microwave heating applications is continuously growing, because of the special mechanisms of microwave irradiation for energy transfer. On the contrary of the conventional heating mechanisms, energy is delivered directly into the materials during microwave heating due to the molecular level interactions with high frequency electromagnetic field. Because of the high energy density and volumetric heating effect, microwave irradiation is suitable to achieve very short process time, and, in some cases, microwave irradiation induces special structural properties or new way for chemical reactions (Kappe, 2004).

Depending on the physicochemical structure and composition of processed material, and the applied frequency range, heating mechanisms of microwave irradiation is occurred by dielectric polarization and/or ionic conduction. Orientation polarization or diploes rotation occurs due to the reorientation of permanent dipoles in oscillating electromagnetic field (Barba and D'Amore, 2012). The materials containing free electrons charge polarization can be observed caused by the modification of position of electrons, resulted in non-uniform distribution of charges.

In the industrially scale used microwave frequency ranges, and mainly for high water contented materials the dipole rotation is the dominant mechanisms, but ionic dissipation phenomena can be also occurred, if ions are presented in the irradiated materials (Brodie et al., 2014). In complex structured materials both mechanisms can be determinative at the same frequency, for example if the state of water content is changed. If thermal or mechanical stress was applied cell walls can disrupt, therefore the intracellular components are released increasing the free water content.

Extracellular polymer substances (EPS) of sludge form a complex physicochemical structure with low bioavailability. In raw sludge the organic matters are presented in particulate from, what decrease the theoretically achievable biodegradation rate (Neyens et al., 2003). In primary sludge, especially if it is produced from food industry effluents, macromolecular components are the main part of organic matter content. Divalent cations bind to polysaccharides and proteins of EPS matrix form connected structures of micro-flocs, and increase the size and stability of sludge floc. Therefore, in most cases pre-treatments are need to increase the availability of substrate before biological utilization of sludge.

Among the thermal pre-treatment methods microwave irradiation could be a promising alternative for process operated by conventional heating. Microwave has strong effect on microbial destruction, microwave process need significantly shorter time demand than needed for conventional heat treatments. Depending on the heating rate and final temperature during the processes, with the application of microwave pre-treatments higher disintegration degree can be achieved. Therefore the higher disintegration degree and higher organic matter solubility led to higher biogas yield in AD process.

Beside absolute value of biogas production, the biogas production rate presents key issue to evaluate the efficiency of a pre-treatment method. Efficiency of microwave pre-treatments depends on the type and condition of anaerobic digestion. Thermophilic digestion suitable to achieve higher biogas product, the effect of pre-treatments are slightly than that of obtained for mesophilic temperature ranged AD tests (Koupaie and Eskicioglu, 2016).

Alkaline treatments, especially if it is associated by thermal methods, suitable to increase the disintegration, accelerate the anaerobic digestion and enhance the biogas production, as well (Dogan and Sanin, 2009). For alkaline pre-treatments NaOH is more effective than $Ca(OH)_2$ (Kim et al., 2003). But overdosing of NaOH can decrease the efficiency of bicarbonate buffer system

of anaerobic digesters, inhibiting the decomposing activity of anaerobic microorganisms. Appropriate alkaline dosage is efficient for floc disintegration but strong alkali condition should be avoided if sludge contains lipids, because of the saponification reactions.

Researches verified that ultrasonic-acid pre-treatment of municipal waste activated sludge (WAS) the release of organic matter and disintegration degree can be improved, if pH decreased. Shear forces generated by sonication disrupt the flocs then macromolecular components are more effectively exposed to H+ ions (Sahinkaya, 2015). Pre-treatment of municipal WAS under acidic condition led to 4-6 times increment of carbohydrate and protein solubility. In batch mesophilic AD tests biogas production increased by 17% and 32% if acidic treatments were carried out at pH 2 and pH 1, respectively.

2. Materials and Methods

Sludge sample was originated from the sedimentation tank of the primary wastewater treatment line of a dairy factory. Sludge samples were kept refrigerated before processing. Dairy sludge has TS and COD content of 3.2% and 21100 ± 320 mgL^{-1}, respectively

Microwave pre-treatments were carried out in a tailor made continuously flow operated microwave equipment. The magnetron operated at a frequency of 2450 MHz, power was changed continuously in the range of 100 to 700W. Sludge flow through the microwave reactor was ensured by peristaltic pump.

Specific microwave irradiated energy (E_s, kJ L^{-1}) was determined from the volumetric flow rate (Q, Ls^{-1}) and the power of magnetron (P_m, W).

$$E_s = \frac{P_m}{Q} (kJ\ L^{-1}) \quad (1)$$

Alkali and acidic treatments were carried out before entering the sludge into the microwave reactor dosing NaOH or H_2SO_4, respectively.

Anaerobic biodegradability was characterized by biogas production determined by batch mesophilic anaerobic digestion (AD) tests. Biogas production was measured at 37 ± 0.5°C for 30 days by pressure increment method. AD tests were carried out continuously stirred sealed serum bottles bottle with volume of 250 mL. The change in headspace pressure was detected by OxiTop® Control (WTW, Germany) manometric measuring heads in an interval of 12 hrs..

Biogas volume was calculated from the pressure increase and the volume of headspace using the ideal gas law. pH of sludge samples was adjusted to 7.2 before the AD tests. Biogas yield was given for total solid (TS). For seeding munici nhhhhhpal digested sludge was used from an operating anaerobic digester.

Biodegradability under aerobic condition was characterized by the change of biochemical oxygen demand (BOD) in the soluble fraction of organic matters. Biochemical oxygen demand was measured in a respirometric BOD system thermostated at temperature of 20·C for 5 days.

3. Results and Discussion

Results of AD tests show, that both the alkaline and acidic pre-treatment assisted by microwave irradiation verified suitable to increase the biogas yield from dairy sludge. Exposed the sludge to MW irradiation with Es of 220 kJ L^{-1} and MW power of 536W carried out alone (without chemical dosage) biogas yield of near 400 mL gTS^{-1} could be achieved (Figure 1.). Biogas production for combined MW/chemical pre-treated sludge was influenced by the Es and microwave power, as well.

At lower power level (536W) and using lower alkaline dosage (0.2 and 0.35 gNaOH/gTS) increasing of NaOH dosage or irradiated MW energy led to increased biogas yield (Figure 1.a). At higher power level (700W) there was not observed further significant increment in biogas production when energy intensity was increased from 170 to 220 kJ L-1 or the concentration of added NaOH was increased from 0.35 to 0.5 gNaOH/gTS (Figure 1.b).

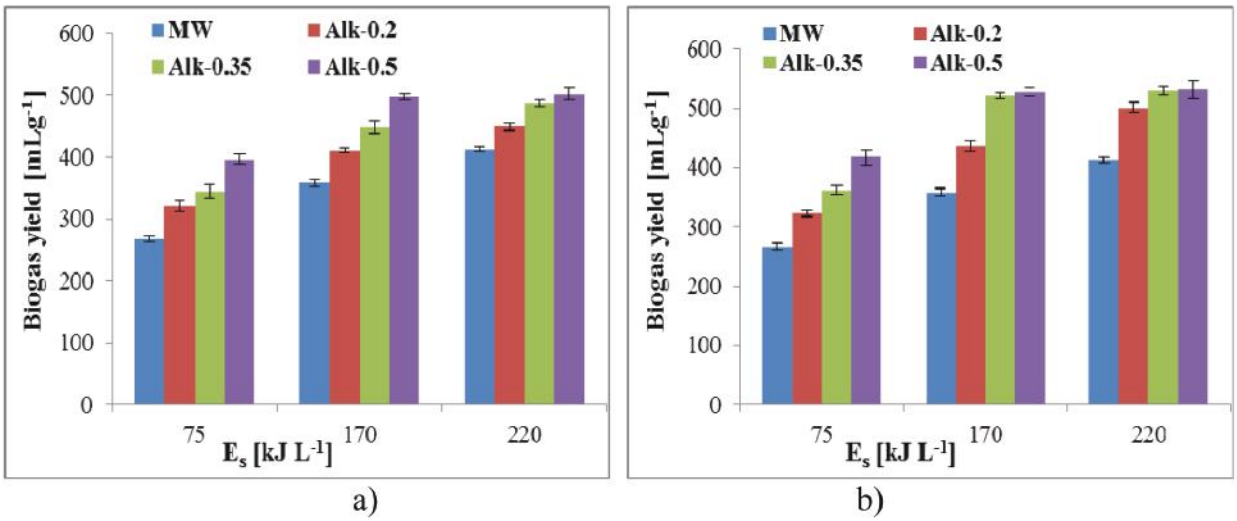

Figure 1. Biogas production of microwave-alkaline pre-treated sludge (MW power of 536W (a) and 700W (b))

Considering the effects of microwave/alkaline pre-treatment can be concluded that for achieving the same biogas yield enhanced energy intensity enable to reduce the alkaline dosage, or rather, increased alkaline dosage make possible to decrease the energy intensity of MW irradiation. From energetically aspects, alkalization of sludge improve the biogas production, and alkaline dosage before thermal pre-treatment of sludge make suitable to reduce the energy demand of microwave process.

Compare the effect of combined acidic/microwave pre-treatment on biogas yield to that of obtained from

alkaline/microwave process it can be summarized, that acid dosage improve the biogas yield, but achievable maximum biogas yield is lower than that of determined for alkaline pre-treated samples (Figure 2.).

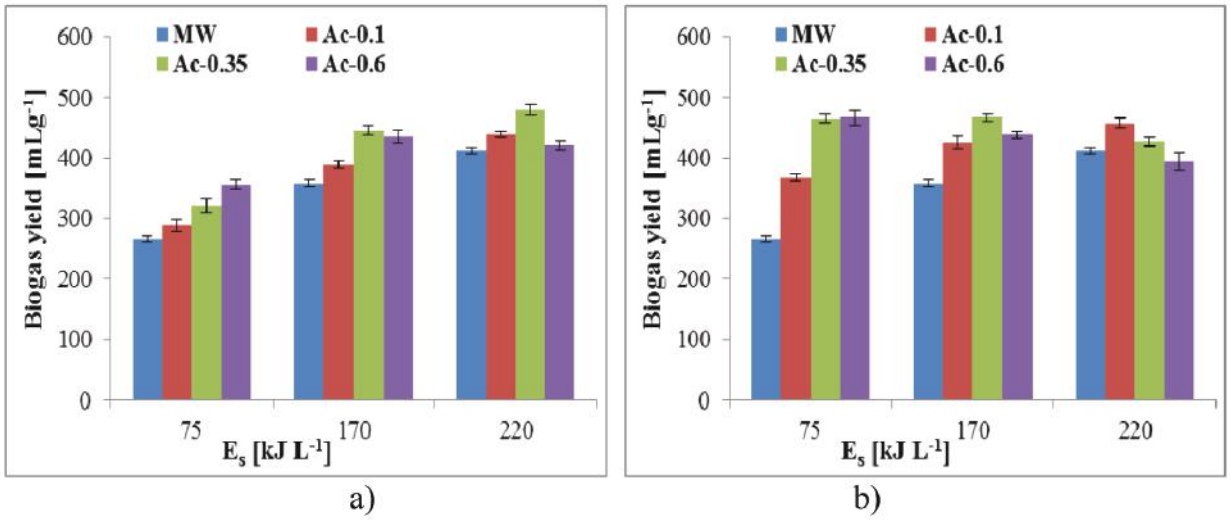

Figure 2. Biogas production of microwave-acid pre-treated sludge (MW power of 536W (a) and 700W (b))

In the case of microwave irradiated sludge dosed acidic before pre-treatment, the enhancement of energy intensity with increased acid dosage can led to decreasing tendency of biogas production. At 536W power level and applying energy intensity of 220 kJ L^{-1} enhanced acid dosage from 0.35 to 0.6 gH_2SO_4/gTS cause 11% decreasing in biogas yield (Figure 2.a). At higher power level (700W) the same tendency (peak value followed by decreasing in biogas yield) was observed for pre-treatment with 170 and 220 kJ L^{-1} (Figure 2.b). Increasing of microwave power under acidic condition contributed to take place chemical reaction between the organic components derived from partially hydrolyzed macromolecules which produce heavily biodegradable and less soluble product (Takashima and Tanaka, 2014).

For comparison purposes, the shorter time biodegradation of microwave irradiated and acidified or alkalized sludge samples was also examined under aerobic condition. For characterization of aerobic biodegradability the biochemical oxygen demand was measured for 5 days from the separated soluble organic matter fraction of sludge. Similarly to the results obtained for anaerobic digestion it was found that microwave irradiation applied alone is suitable to increase the concentration of biodegradable organic matters, as well (Figure 3.). Increment of BOD was influenced by the energy intensity and the chemical dosage, as well.

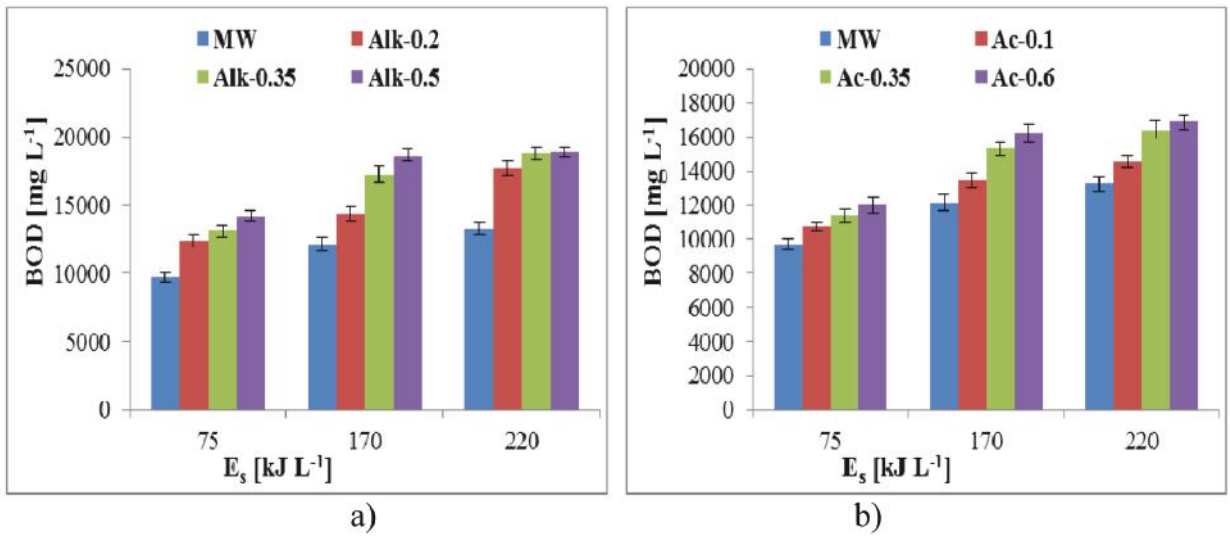

Figure 3. BOD of alkaline (a) and acidic (b) MW pre-treated sludge (MW power=536W)

Applying of acid/alkali dosage followed by microwave irradiation increased further the biodegradability of sludge. Alkaline pre-treatment enhance the efficiency of sludge flock disintegration during thermal processes, therefore improve the substrate availability for decomposing microorganisms (Dogan and Sanin, 2009). Acidic condition assists in the disruption of extracellular polymeric substances and hinders the reflocculation (Liu et al., 2016). These establishments related to municipal waste activated sludge were verified for dairy sludge, as well.

Acid dosage and as well as alkaline dosage combined the intensive heating effect of microwave irradiation were suitable to increase the BOD. Maximum achievable BOD concentration was higher for alkaline method than for acidic/microwave pre-treatments. Using the same range of Es, microwave power and alkaline/acidic dosage than was applied before AD tests decreasing tendency of BOD was not observed if Es or acid dosage increased.

4. Conclusion

In our work the applicability and efficiency of microwave irradiation combined with acid/alkaline dosage, as thermochemical pre-treatment method, was investigated. Our results show, that microwave irradiation alone was suitable to increase both the aerobic and the anaerobic biodegradability. Pre-treatments, where sludge alkalization was combined with microwave irradiation the biogas production enhanced, but the effect of two methods could not be considered synergetic. Increased microwave power or irradiated energy enables to reduce the alkaline dosage to achieve the same biogas yield. Microwave treatment under acidic condition increased the aerobic biodegradability, but beyond a certain value of irradiated energy level or acid dosage decreasing tendency was found in the change of anaerobic digestibility. Our results verified that beside microwave-alkaline pre-treatment methods, the microwave-acidic process is suitable as potential pre-treatment method, but particularly is capable for enhanced aerobic biodegradability of dairy sludge

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ALTERING OF MARZIPAN FOLLOWED UP BY PHYSICAL MEASUREMENTS

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Abstract

Reducing sugar content of marzipan samples were measured by analytical method (Schrool-Regenbogen method - for control), texture analysis was done by penetrometry, electric properties were measured by conductometry and hyperspectral images were taken regularly for 16 days. The main wavelengths which gave the best discrimination results among the days of storage were between 960 and 1100 nm. The type of the marzipan was easy to distinguish with the hyperspectral data; the biggest differences were to be found at 1200 and 1400 nm. The spatial distribution of penetrometric, electric and spectral properties were also characteristic to fructose content.

Keywords

hyperspectral imaging, marzipan, fructose content, conductometry, penetrometry

1. Introduction

Marzipan is a delicacy which is made primarily from almond and sugar. In some countries it can contain other nuts (e.g. apricot kernel) as well. Blanched almonds are mixed with sugar-glucose or sugar-invert syrup mixtures in different sugar-almond ratios. For its significant taste bitter almonds are also used in the production (up to 1% of the total nut weight should be bitter). According to the Codex Alimentarius Hungaricus the marzipan products are classified according to their sugar-almond ratios, the sugar content (expressed in sucrose, on dry base) is 35, 50, 67 or 75 w/w%.

Although during the ageing of marzipan the total sugar content is not altering, the ratio of the different sugar components changes. Invertase enzyme transforms the non-reducing sucrose into glucose and fructose molecules [1].

Unlike saccharose (sucrose) fructose is highly hygroscopic; therefore the drying out of the marzipan is reduced.

The reducing sugar content (fructose) is measured in general by titrimetric or iodometric analytical methods (e.g. the Schoorl Regenbogen method) [2], which are time and solvent consuming, and require analytical skills.

Other techniques such as HPLC and ion chromatography are also used in direct sugar analysis. However to use these methods the sample preparation is crucial, as most methods of sugar analysis requires a clean aqueous extract to work on [3], and in marzipan sugar is present in a matrix of lipid and protein.

Christensen et al. [4] used in their study a set of 32 marzipan samples of nine different recipes to measure their composition with different types of NIR spectrometers. The marzipan samples were analyzed chemically and measured on six different spectrometer set-ups. Partial least squares regression (PLSR) method was used to make calibrations to moisture and sugar content. In their model the root mean square error of cross-validation (RMSECV) for the prediction of the moisture was found to be 0.36% w/w moisture (range 7–19%). The sugar content was predicted with a RMSECV of 1.43% w/w (range 33–68%) [4].

The same data set was used for the work of Westad et al. [5], where relevant wavelengths data were searched for the best differentiation. Sugar and water constitute the two major chemical components in the marzipan data, and as expected the spectral pattern reveals a distinction between O H vibrations (sugar and water) and C H vibrations (sugar). For instance, the broad water bands in the NIR regions at 800–1100 nm (O H stretch, 2. overtone) and around 1900 nm (O H stretch/deformation combination) are well correlated to the O H deformation band in the 700–800 cm−1 region of the IR spectra. The 1200 nm NIR region (CH stretch, 2. overtone), on the other hand, show significant correlations to IR bands around for instance 820 cm−1 (CH deformation) and 1030 cm−1 (CO stretch). Last, the NIR bands around 1400–1500 nm are related to both O H stretch vibrations and C H combinations [5].

Hyperspectral imaging has been used on different food products; for example to measure the moisture content of carrots [6, 7], ham [8] and soy beans [9]. The same technique was used on plants, too [10].

Aim of the present study was to evaluate of the use of hyperspectral imaging technique, conductometry and penetrometry to follow the changes induced by altering fructose content of marzipan during storage.

2. Materials and Methods

Marzipan samples of 3 different sugar: almond ratios (1:1, 2:1, 3:1) were produced under the same manufacturing parameters. Prismatic samples (rods) of the same geometry were cut out of

the marzipan blocks. Samples were stored at constant temperature of 17°C in a closed cabinet. Storage lasted to 16 days after production, as this time is enough to finish the sucrose inversion.

Measurements were taken on day 1, 3, 7, 10, 14, 16 days after production.

Reducing sugar content was measured by the Schrool Regenboogen method according to the Hungarian standard MSZ 20900/5-1989.

Hyperspectral imaging were done using Headwall push broom system (900-1700 nm range, 256*320 InGaAs sensor matrix, 14 bit A/D, 800 nm/155 band = 5.16 nm/px spectral resolution, 214*100 mm field of view: 686*320 px image size, 100 mm/320 px = 312 µm/px spatial resolution, 45/0 illumination geometry, Headwall Photonics, Inc, Fitchburg, MA, USA) and Argus calibration and data acquisition software [11]. The stable setup, proper calibration method and pixel-noise handling provided the same result for a flat surface, as a conventional spectrophotometer. The mean spectra of selected region of interests (ROI) were preprocessed and saved by Cubrowser Matlab algorithm as Figure 1 shows [11].

Texture analyser Ta-Xt2 was used for penetrometric texture analyses. The maximal force (rupture point) was measured along drying rod at 7 points during 4 weeks of storing.

Conductivity of the samples was measured with HP4284A Precision LCR Meter that acquires data in 20 Hz to 1 MHz test frequency range. Tests were made on 48 selected frequencies at 7 points of drying rod during storage time.

For statistical analyses discriminant analysis and principal component analyses in SPSS program were used.

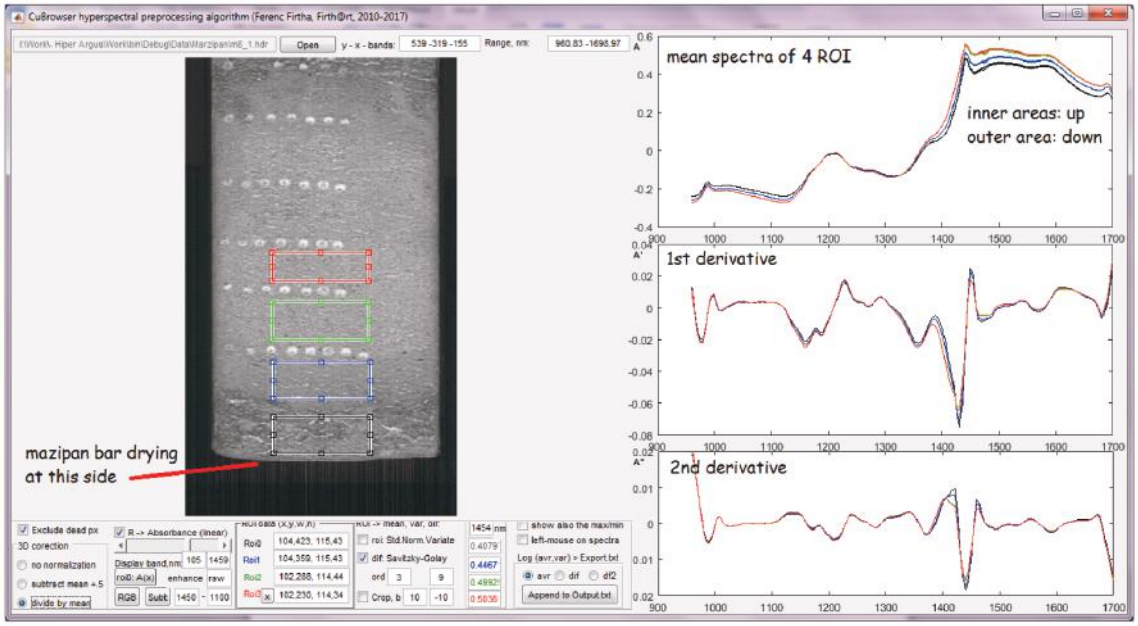

Figure 1. The spectral crossection at 1445nm of a hypercube in Cubrowser algorithm

3. Results and Discussion

During the storage of the marzipan samples as expected sucrose inverted into glucose and fructose, as it can be followed on Figure 2. The speed of conversion was the highest in the first 3 days of storage. In case of a 2 sugar: 1 almond sample (67% of sugar in the recipe) it seems, that the conversion has not ended after 16 days, which is not in harmony with the literature data. At the end of the storage, the reducing sugar content has reached a maximum of 14.3% in case of 1 sugar: 1 almond marzipan and a maximum of 9.5% in 3 sugar: 1 almond marzipan.

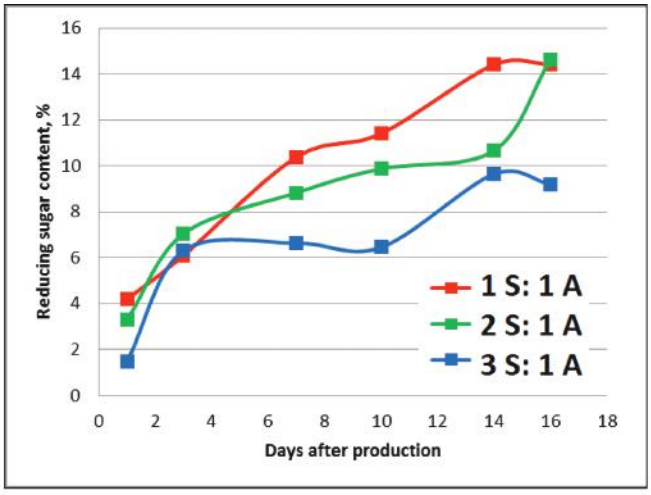

Figure 2. Changing of the reducing sugar content during storage of different marzipan samples (ratios of S- sugar, A-almond)

Correlation of storage time and hyperspectral data

The images of the marzipan prisms were divided into 7 regions. The spectra of these regions were averaged and further used for the evaluation Evaluations were done on the raw data, the first derivate and on the normalized raw data and its first derivate using Argus software developed by Firtha [11]. These data were then used for further analysis to define correlations between storage time and hyperspectral data and type of marzipan and spectral data.

In the first analysis the correlation was studied between the day of storage and the spectral data, not taken into account which sugar to almond ratio the marzipan sample had. During the storage of marzipan the shape of the spectra have not changed significantly, independently from the type of marzipan. The measured values on day 3 were outstanding most probably connected to a measurement failure, and therefore those values were left out from further analyses.

Using the discriminant functions a classification was done, where 88.6% of the original grouped cases were correctly classified, and using randomly selected data a cross validation resulted also in a good classification (83.8% of samples groups were correctly classified).

The discriminant function coefficients show, that the lower wavelenghts (960-1100 nm) are the most useful to define how many days were gone after production.

Correlation of sugar to almond ratios and hyperspectral data

Figure 3 shows the spectral data of the different marzipan samples after the first and sixteenth day of storage. The biggest differences can be seen around 1200 nm, which is, where oils are absorbing the most light according to the literature data. In the marzipan, where the same amount of sugar and almond was, the oil content is the highest among the samples, so its reflectance is the biggest on this wavelength. Above 1400 nm the spectra of the 1 sugar: 1 almond sample is smooth, where the other samples show peaks. According to literature data in this region sugars and water significantly form the reflectance values [12].

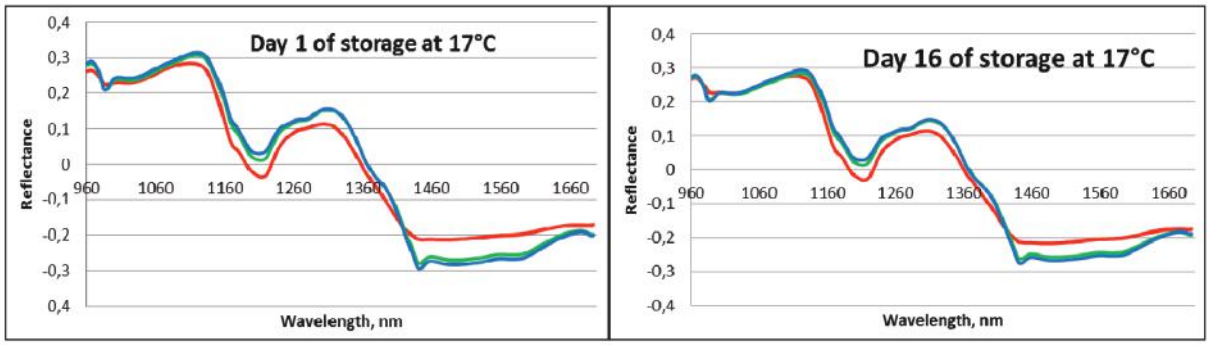

Figure 3. Reflectance spectra of marzipan samples day 1 and day 16 after production, red line 1S:1A, green line 2S:1A, blue line 3S:1A, where S is sugar, A is almond, ratios on dry matter base

With discriminant analysis a clear classification could be done among sample groups according to their sugar content. The group centroids are in case of 2 and 3 marzipan samples (2 sugar : 1 almond and 3 sugar: 1 almond ratios) closer to each other, then in case of sample 1 (1 sugar : 1 almond). Along function 1 better dicrimination has been reached, then along function 2. There was a 100% success in the classification of the groups,also in cross-validation.

In this analysis not only the earlier mentioned 1200 nm (oil content related region) can be found as a significant wavelength for the discrimination, but also the lower regions (960-1000 nm) are important factors.

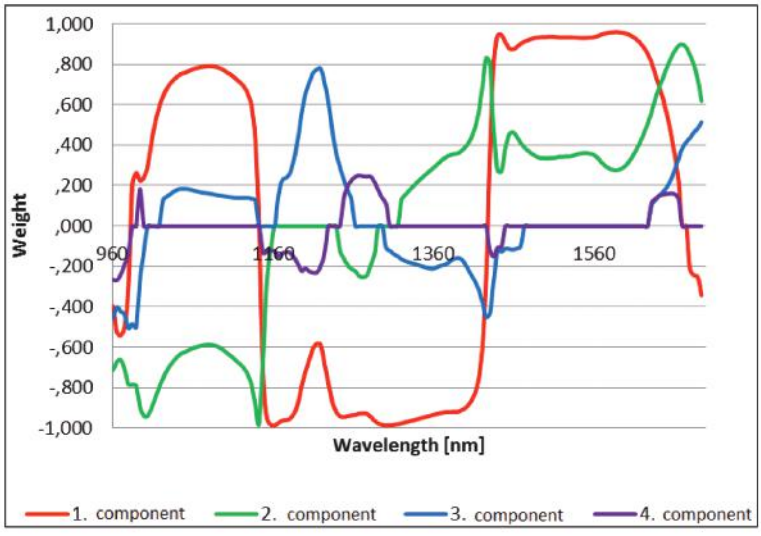

Figure 4. Weights of the wavelengths as independent variables in PCA

Using discriminant analysis we could distinguish among the marzipan samples of different sugar content. With principal component analysis (PCA) we identified the wavelengths which gave the biggest significant differences between the studied samples (Figure 4) Wavelengths of which weight is above 0.25, have a significant effect in the components of the discrimination in PCA. It is interesting to see, that the signs of each component is changing at the wavelengths which were mentioned earlier in the discriminant analysis.

Discussion of the penetrometric, electric and hyperspectral data

Hardness of marzipan can be described as the maximum force needed to rupture the surface of the sample. Conductivity of marzipan is directly connected to the bound state of water. In Figure 5, three graphs can be seen representing the hardness, the impedance and the reflectance values of the marzipan rods, measured 2 times a week during a 4 week storage period. On the x axis the dimension of the marzipan rod is described. 0 in this case means the middle point of the rod. Although the force/impedance/spectral values do not give an exact representation of the fructose content, the spatial distribution of the data shows, how the sides are drying out more, then the inner parts of the rods. In the middle of the rods, where the fructose could withhold the drying out of marzipan, hardness remained lower, impedance of the samples were smaller and the spectral data showed also lower values at 1450 nm, which is the region connected to water.

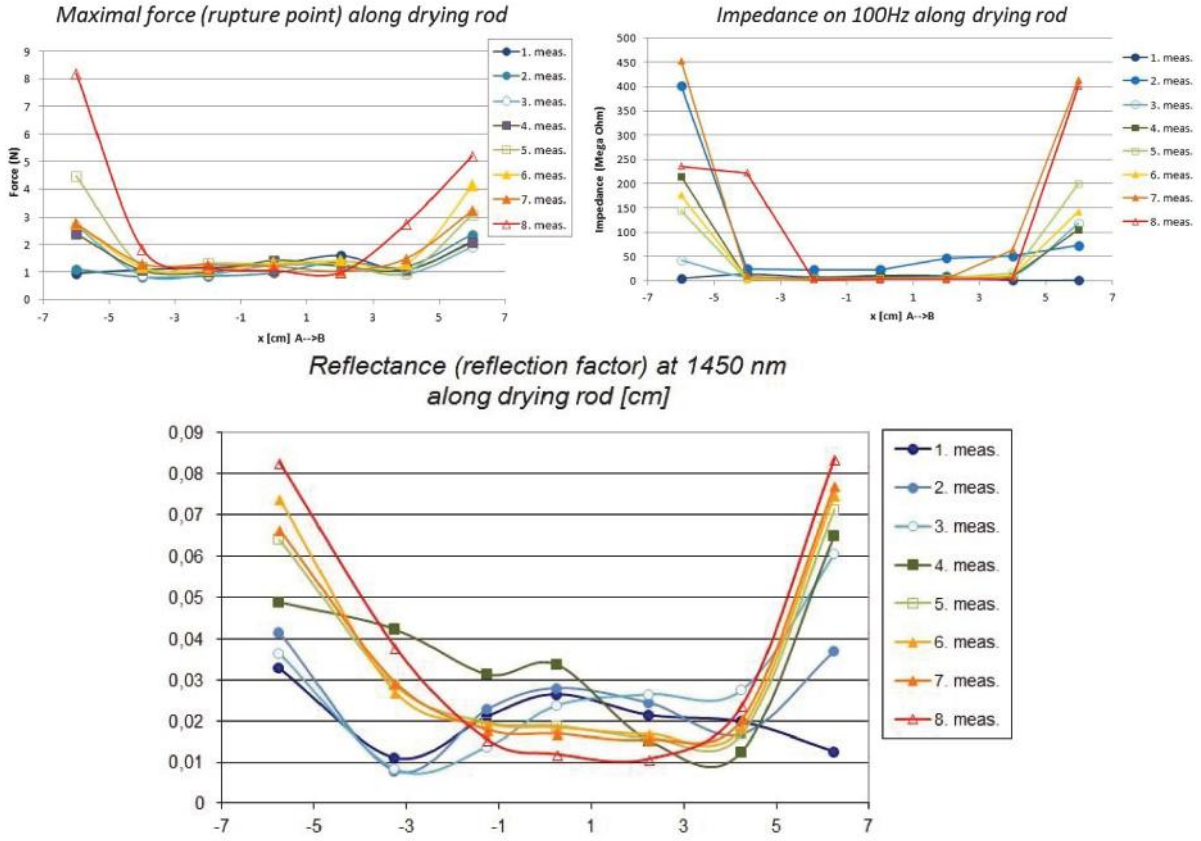

Figure 5. Hardness (maximal force), impedance and reflectance at 1450 nm of marzipan rods during storage at 17°C, represented as measured on the surfcae of a marzipan rod from side to side

Measuring fructose content of marzipan by optical methods faces many obstacles. Polarimetry is not of use, because there are more sugar components and therefore the diffuse reflection of the surface disperses the polar plane.

Spectroscopy is also not suitable, because one can differentiate only between monosaccharides and disaccharides, but not between sugar type as glucose and fructose (both are monosaccharides, with similar spectra).

However as the fructose is hygroscopic, it attracts and binds water, the spatial distribution of properties, which are depending on the water content (like absorption at 1450 nm), is characteristic.

The moisture content of a drying wall from a normal material is cosine-like (see Fourier). In case of hygroscopic material, like fructose, the spatial distribution is constant in the middle and changes on the edges only. This can be followed by hyperspectral method, thus it allows checking the fructose content of a marzipan sample.

4. Conclusions

Hyperspectral imaging has the advantage, that samples can be measured without polluting them. Although this measurement cannot give exact data about the fructose content of marzipan, the spatial distribution of the electric, penetrometric and hyperspectral data were similar.

With discriminant analyses we were able to make classifications according to the sugar content of the marzipan and it was possible to distinguish among the days of storage as well. The fructose content of marzipan cannot be measured by usual optical ways (polarimetry, spectroscopy), but since fructose is hygroscopic, the spatial distribution of spectral properties can be characteristic.

Further research is needed to see, if hyperspectral technique can be used on packed samples, too.

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ENHANCING BIOGAS PRODUCTION KINETIC OF MEAT INDUSTRIAL WASTEWATER BY MICROWAVE PRETREATMENT

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Abstract

This study investigated the effects of microwave pre-treatment of meat industrial wastewater in order to enhance its anaerobic digestibility. Wastewater was treated in a continuous flow microwave system at different magnetron power (300W, 500W, 700W), volumetric flow levels (6 Lh^{-1}, 15,5 Lh^{-1}, 25 Lh^{-1}) and number of treating (1, 3, 5). After treating these samples anaerobic biodegradation was carried out and correlation was investigated between power of the magnetron, volumetric flow, number of treating and biodegradability. Experiments indicated that pre-treated samples gave higher yield of biogas compared to untreated one. The maximum yield of biogas production was obtained at 700W irradiation power, 6 Lh^{-1} volumetric flow and 5 times treating.

Keywords

pretreatment, biogas, microwave, anaerobic digestion

1. Introduction

Most of the activities using water produce sewage. As the general demand for water is growing, the amount of waste water produced and the pollution load are continually increasing worldwide. Vast majority of waste water is dispensed directly into the environment without proper treatment, to the detriment of human health, economic productivity, quality of freshwater resources and ecosystems. All of these have an impact on community well-being and the livelihood of the population.

Despite its growing volume, sewage is also a reliable source of alternative water source if the paradigm of sewage treatment is shifted from "treatment and disposal" to "recycling and resource recovery" practices. In this sense sewage is no longer a problem that requires a solution but rather a solution to the challenges that society faces today. Waste water can be a cost-effective and sustainable energy source, and it may also contain nutrients, organic substances and other useful by-products. In the context of a circular economy in which economic development is in balance with the protection of natural resources and environmental sustainability, sewage is a widely available and valuable resource [1].

As the wastewater generated by the food industry contains very high levels of organic matter, it seems to be an obvious solution the anaerobic degradation of it and further use of the generated biogas. In addition, anaerobic fermentation reduces the amount of pathogens, stabilizes sewage without adding further additives. In several parallel and sequential processes, organic materials mainly produce methane, carbon dioxide, other gases and residual biomass.

Sewage is mostly composed of microorganisms and extracellular polymer materials produced by the cells as part of their metabolic activity. Most of the organic matter is located within the microbial cell membranes. The cell surface of microorganisms is a semi-rigid structure that is capable of protecting the cell from osmotic lyses. This cell wall contains glycan fibers crosslinked with peptide chains that are resistant to biodegradation. For this reason, in order to achieve acceptable biodegradability, traditional digestion techniques require long hydraulic retention times. The efficiency of digestion can be increased by breaking the microbial cell walls and releasing the organic materials inside the cells [2].

The anaerobic degradation of organic matter takes place in four steps: hydrolysis, acidification phase, acetogenic phase and methanogenic phase [3]. Hydrolizing bacteria transform complex high molecular organic matter, polymers (proteins, fats, carbohydrates) into simpler compounds (amino acids, glucose, fatty acids, glycerin). These monomer hydrolysis products are further broken down by other bacterial groups. In some cases, hydrolysis phase is slow, so it can be a decisive step in the process of anaerobic digestion. In order to increase the efficiency of the hydrolysis it is necessary to apply various pre-treatment methods which for making the material available. Numerous methods can be used physical (mechanical, thermal etc.), chemical (ozonolysis, acid hydrolysis, alkaline hydrolysis, etc.), biological (fungi, enzymatic hydrolysis, etc.) pre-treatment or combination of them [4, 5 (Mosier et al, 2005; Sun and Cheng, 2002)

This study deals with the optimization of thermal pretreatment based on microwave heating, which provides rapid warming in the total volume of the material.

2. Material and Method

Treated meat waste water comes from a medium-sized meat processing plant, primarily from the process of equipment rinsing and cleaning (slicing and packaging machines, smoking chambers). A tissue filter was used to remove larger floating solids (Table 1).

Table 1. Characteristics of wastewater

Parameter	Value
Total solid (TS) (mgL^{-1})	3210±296
Total organic carbon (TOC) (mgL^{-1})	834,1±35,3
Lipid(mgL^{-1})	115,1±21,7
Protein (mgL^{-1})	379,4±21,2

Microwave pre-treating system

Microwave pre-treating system (Fig. 1) contains a water-cooled, variable-power magnetron (M) operating at 2450 MHz. High-voltage power supply (NF power supply) feeding the magnetron consists of two transformers, one of them produces cathode heating voltage and heating current, the other produces the anode voltage which can be controlled by the primary circuit of an external auto-transformer. With this device (PM scaled TTR) the power of the magnetron can be set as well. Electromagnetic energy of the magnetron spread over a resonant slot. Getting through this slot the energy gets in the toroidal resonator. (Kovács et al, 2012). During the operation of toroid resonator energy is given to the treated material. As a result of energy transmission the temperature of the material rises and the dielectric properties change continuously. The effect of the microwave energy intake, variable power, impedance and dielectric relationships are formed in the microwave resonator. Some of these can be measured (eg. power dissipation, reflected power), some of them can only be determined by calculation, knowledge of the other parameters (J. Zhu et al, 2007). Material is transferred in the continues-flow microwave treating system by a peristaltic pump (PP) with variable flow (Figure 1).

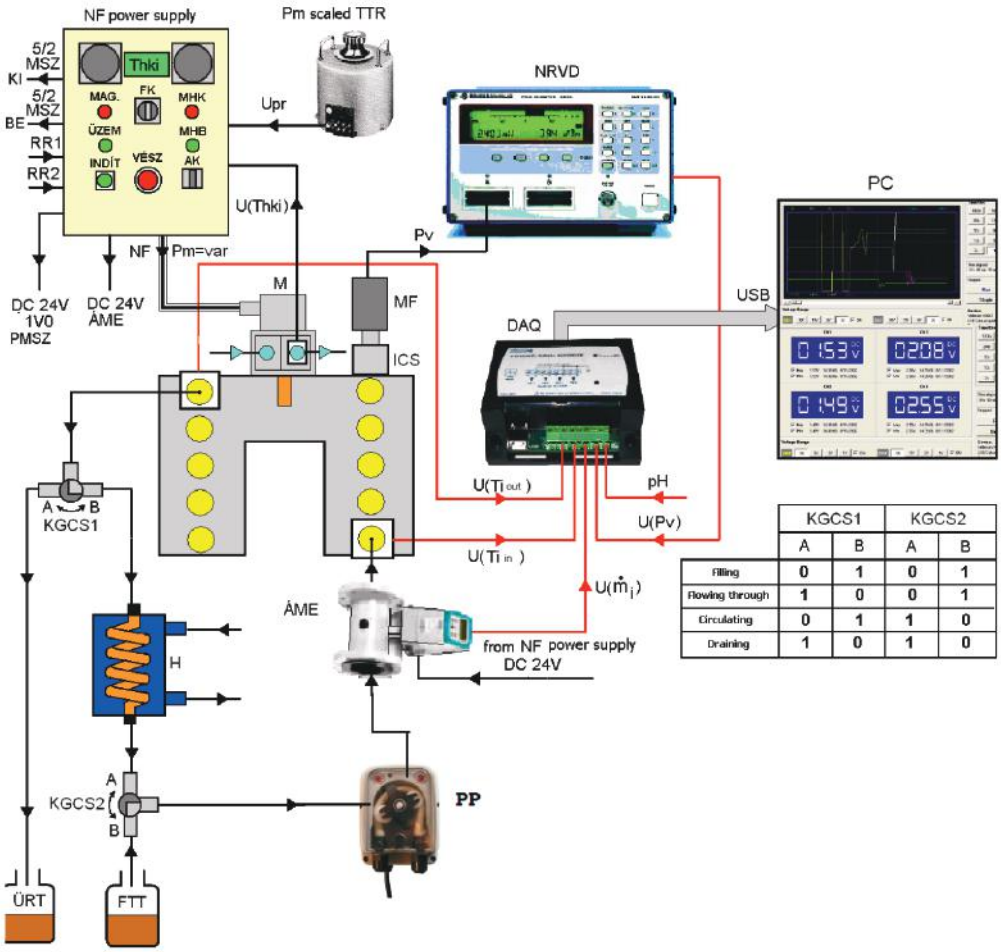

Figure 1. Microwave pre-treating system

Fermentation process, biogas measurement

Anaerobic digestion (AD) tests were carried out under controlled mesophilic temperature range (35±0,2 °C). in 12 mini continuously stirred laboratory scale reactors with 250 mL total volume, equipped with Oxitop C.

3. Results and Discussion

Effects of magnetron power on biogas production

Power of the magnetron (PM), flow rate (FR) and number of treatings (NT) profiles are shown in Table 2 with the associated responses which is biogas production.

Table 2. PM, FR, NT settings and responses associated.

No.	Power of the magnetron [W]	Flow rate [Lh^{-1}]	Number of treatings [-]	Biogas production [mL]
1	700	25	5	298
2	700	25	1	295
3	700	6	1	315
4	300	25	5	247
5	300	6	5	258
6	300	25	1	238
7	700	6	5	316
8	300	6	1	250
9	500	15,5	3	285
10	500	15,5	3	280
11	500	15,5	3	283

Results could be represented as function of PM, the correlation coefficient (R2) is 0,91 (Figure 2).

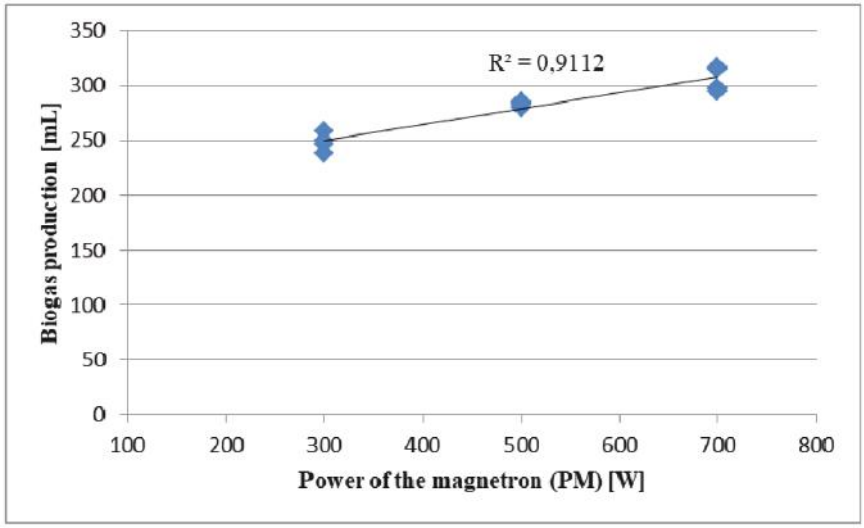

Figure 2. Biogas production as function of PM

Kinetic study of biogas production

Kinetic study of biogas production has been conducted for description and evaluation of methanogenesis by fitting the experimental data of biogas production to various kinetic equations. Biogas production rates have been simulated using linear, exponential plots. It has been assumed that biogas production rate increases linearly with increase in time and after reaching a peak value it decreases linearly to a low significant value. The linear equation for biogas production rate can be expressed by the equation below (M. D. Ghatak and P. Mahanta, 2014; S. Kumar et al, 2004)

$$y = a + bT \quad (1)$$

where y is biogas production rate (mL), T is retention time in days, and a and b are constants obtained from the intercept and slope of the graph plotted y versus T. Slope b is positive for the ascending limb and negative for the descending limb.

The exponential plot can be represented by the equation below

$$y = a + b^{cT} \quad (2)$$

where y is biogas production rate (mL), T is retention time in days, a, b and c (day^{-1}) are constants, and c is positive for the ascending limb and negative for descending limb. In this case it has been assumed that the biogas production rate increases exponentially with increase in time and reaches a peak value and thereafter decreases to a low significant value exponentially with increase in time.

The research work has been carried out in order to study the influence of microwave pretreatment on the kinetics of biogas synthesis. Microwave pretreatment could enhance the biogas production potential resulting in enhanced ultimate biogas yield as shown in Figure 3 a) and b).

Figures 4 a) and b) represent linear model fitting of biogas production rates for samples treated at different settings. The coefficient (R2) including both the ascending and descending limbs for all the groups ranged from 0.87 to 0.96.

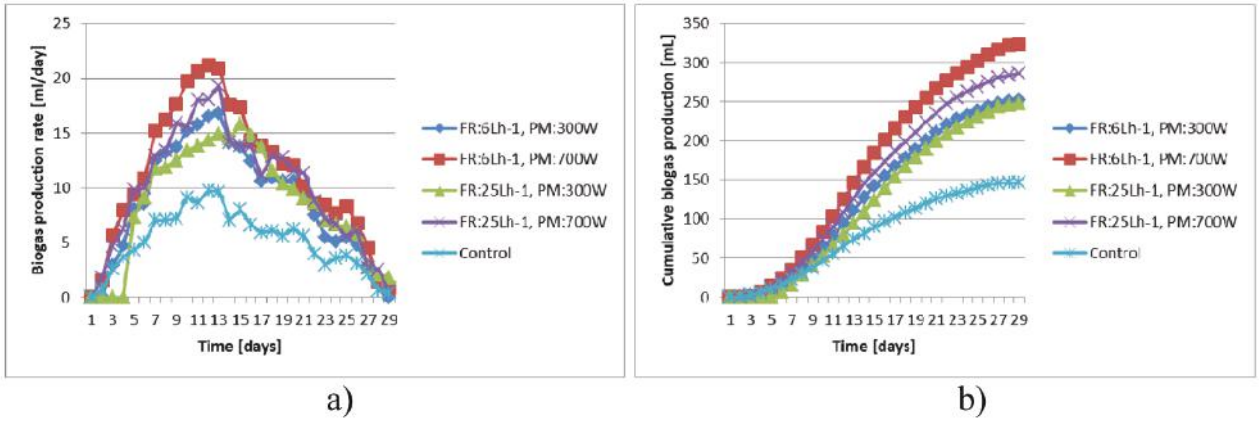

Figure 3. (a) Biogas production rate of samples treated at different settings for a retention time of 29 days. (b) Cumulative biogas production of samples treated at different settings for a retention time of 29 days.

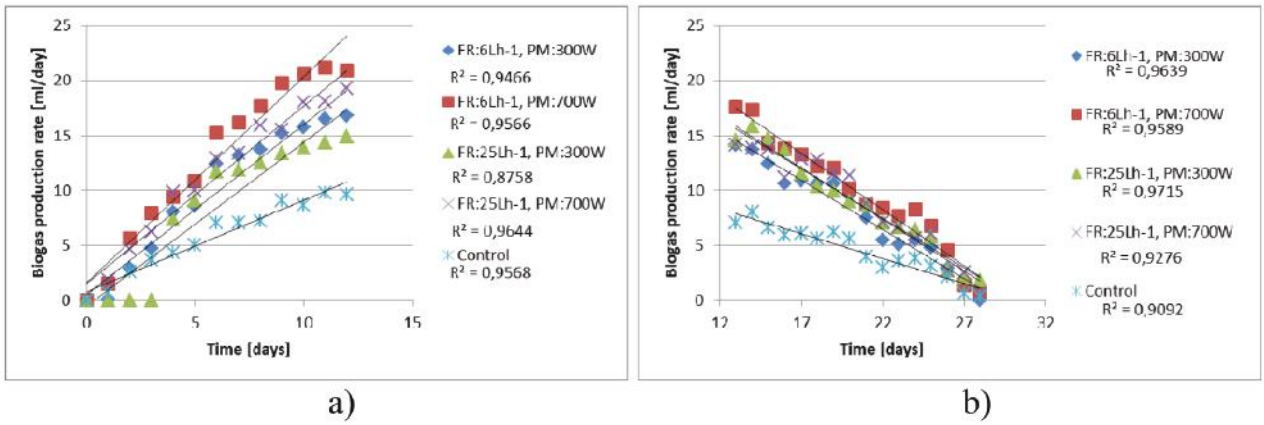

Figure 4. a) Linear plot of the ascending limb of biogas production rate of samples treated at different settings, b) Linear plot of the descending limb of biogas production rate of samples treated at different settings

Similarly, Figures 5a) and b) show the exponential plot of biogas production rates including the ascending and descending limbs for each case. The coefficient of determination *R*2 for the ascending and descending limb has been observed to be in the range of 0.7–0.87, which signifies that linear regression was better than that of exponential plot.

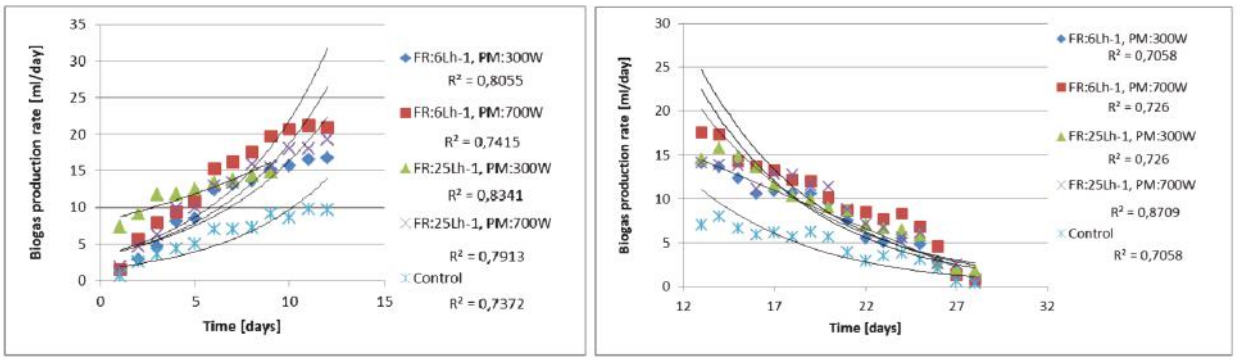

Figure 5. a) Exponential plot of the ascending limb of biogas production rate of samples treated at different settings, b) Exponential plot of the descending limb of biogas production rate of samples treated at different settings

4. Conclusions

Microwave pretreatment improved the kinetics of biogas production; high PM treatment was more effective in preconditioning of the biomass prior to anaerobic digestion and henceforth resulted in higher yield of biogas. Biogas production potential was enhanced by thermal pretreatment which was revealed by the kinetic modeling of biogas production rates and cumulative biogas production. Biogas production rate simulated by linear model showed better correlation than exponential plot.

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CONNECTION BETWEEN RHEOLOGICAL AND ELECTRICAL PARAMETERS OF CANDY GUMS

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Abstract

The elastic modulus and viscosity of gum candy are linearly depended on the applied mechanical stress presumably in consequence of the structure changes in gelatine gel changed under mechanical stress. The electrical impedance spectroscopy can be used for detection such structural changes. The relaxation curves and the electrical impedance spectra of gum candies under various deformations were detected. The measured relaxations were approached with stretched exponential function and the impedance spectra were modelled with a circuit consisting of serial connection of a resistance and a distributed element. The connection of rheological parameters with electrical parameters was determined.

Keywords

candy gums, rheology, electrical impedance, stretched exponential function

1. Introduction

The gum candy is sucrose based, combined semisolid gel, which contains approximately 10% gelatine. The sugar contain (sucrose, glucose syrup, and dextrose in certain proportion) ensures the required texture profile, while the gelatine secures the typical viscoelastic rheological behaviour [1]. The objective texture description can be very important in quality assurance during the manufacturing processes.

In our earlier work the rheological behaviour of gum candies were described with various models – as two, three and four elements (Burgers) models and the best approach was resulted by Burgers model [2]. These models gave good fitting both in creep and recovery curves except of the beginning of curves. Nevertheless the use of stretched exponent function in approaching showed much better fitting in the whole curves [3].

The parameters – elastic moduli and viscosities – of used models were linearly depended on the applied loading stress [2, 3]. The increasing viscosities and elastic moduli can refer to structure changes in gum candies under loading stress.

Really according to Mitchell's [4] comprehensive study of gel rheology, the majority of food materials gels shows linear viscoelastic behaviour up to strain of 0,1 range. If the strain is higher than 0.1, the creep and the stress relaxation of gels would suggest the move and the brake of non-covalent cross links under stress.

The gelatine is a biopolymer protein, obtained by hydrolytic degradation of collagen. Native conformation of collagen is a triple helix held together by inter-chain hydrogen bonding. Above 37°C in aqueous solutions the gelatine molecules exist as separate, disordered chains (coils). When a solution containing around 1 wt% gelatine is cooled to room temperature, the gelatine molecules form an infinite network cross-linked by hydrogen bonding [5]. The role of the coil-helix transition in this mechanism has been thoroughly investigated. Gelatine gels are quite soft and flexible, and the gel strength is dependent on the gelatine concentration [6].

The changes in structure of gum candies under loading stress can be investigated by several physical methods among others with electrical impedance spectroscopy. The conductivity and the polarizability of materials strongly depend on motility of charges and charged groups in macromolecules [7].

The aim of this study was to measure the relaxation curve of gum candies under various deformations and under these deformations to measure the electrical impedance spectrum, too. The measured relaxation curves were approached with stretched exponential function and the model parameters were determined. The electrical impedance spectra were also fitted with Cole circuit model and model parameters were obtained. In this work we try to answer the question is there any effect of loading stress on electrical impedance spectrum or not, and we try to find connection of rheological parameters with electrical parameters.

2. Materials and Methods

Gum candies purchased from local shop were used for both rheological and electrical measurements. The initial average height of gum candy was 9,5±0,3 mm.

Relaxation curves were determined with a texture analyzer Stable Micro System (Godalming, UK). The diameter of measuring head was 2 mm and the speed of head was 0,1 mm/s. At various constant deformations - 0.5, 1.1, 1.4, 2, 2.7, 3.4, 3.9, 4.5, 5, 5.7, 6.2 and 7.2 mm – the decrease of force was detected during 100 s.

The measured relaxation curves were approached with stretched exponential function

$$F = F_e + F_0 e^{\left(-\frac{t}{T}\right)^{\beta}} \quad (1)$$

where F is the decreasing force, F_e is the equilibrium force, F_0 is a constant, t is the time and $\frac{\eta}{E}$ is a relaxation time, η is the viscosity, E is the elastic modulus and β is the stretching exponent. The stretching exponent can characterize the distribution of relaxation times caused by various structures in macromolecular complex [8]. The β stretching exponent was practically independent on applied stress, but depended on applied creeping time in the 30-120 s range [3]. Average of values at various creeping times showed a decreasing tendency at increasing creeping time. At longer creeping time the longer relaxation times appeared and the distribution of relaxation time became wider causing lower stretching exponent value [8].

The magnitude and phase angle of electrical impedance of gum candies were determined with a HP 4284A and a HP 4285A precision LCR meter in the frequency range from 10 Hz – 1 MHz and from 75 kHZ – 30 MHz, respectively. ECG electrodes (Fiab Spa) were glued on the vice-grips. Between the electrodes was the sample and the deformation was realized with removing the vice-grips towards each other. The impedance spectra were measured under the same deformations used in relaxation curves. The impedance spectra were approached with serial connection of a resistance and a distributed element

$$R = R_0 + \frac{R_1}{(1+i\omega\tau)^{\psi}}, \quad (2)$$

where R_0 is the resistance of investigated object extrapolated for infinite high frequency, R_1 is also resistance, the length of the secant of Cole-arc, i is the imaginary unit, $\omega=2\pi f$ is the angular frequency, f is the measuring frequency, $\tau=R_1C$ is the relaxation time, C is the capacity and ψ is an exponent. ψ, similar to β, can characterize the distribution of relaxation times. If the investigated sample is homogeneous then ψ is near to one, but if the sample is inhomogeneous value of ψ is near to zero [7].

From the geometrical data of samples the relative dielectric constant and the specific resistances belong to the R and R1 were calculated

The curve fitting was realized with the Solver function of Excel program. Correlation of the rheological parameters to the electrical parameters was investigated.

3. Results and Discussion

The sum of a stretched exponential function and a constant – equation (1) – is approaching well the whole range of relaxation curves, a typical curve fitting can be seen on Figure 1/A. The expression (2) resulted good approximation of measured impedance spectrum (Figure 1/B). Both the rheological and the electrical parameters were evaluated and represented in the function of applied deformation.

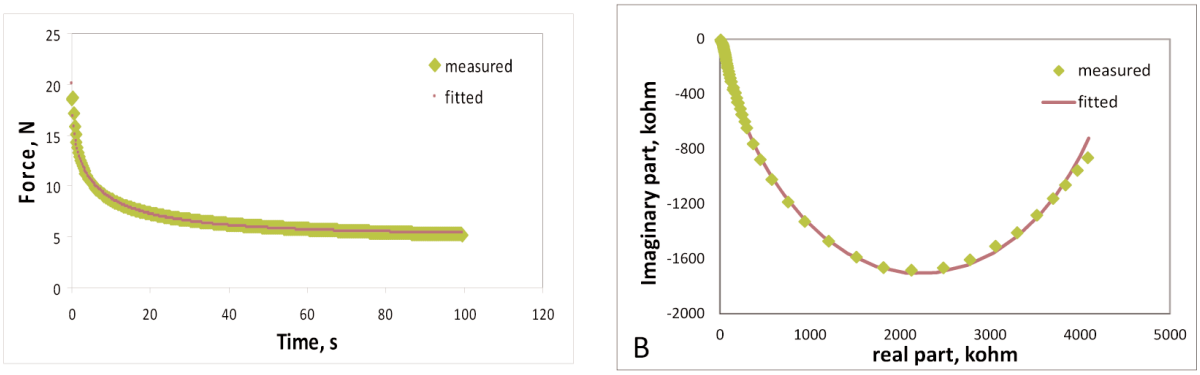

Figure 1. Typical force relaxation (A) and Argand diagram of mpedance spectrum (B) of gum candy

Both F_e and F_0 parameters increased as the deformation increased (Figure 2. A and B). At low deformation – strain less then 10 % - the connection of these force parameters with deformation seems linear. At higher deformations the rate of increase becomes quicker. Relaxation time (Figure 2/C) is increasing at low deformations (lower than 2-3 mm), but at higher deformation remains practically constant. Change of β parameter in the function of deformation shows similar tendency according to increasing of relaxation time.

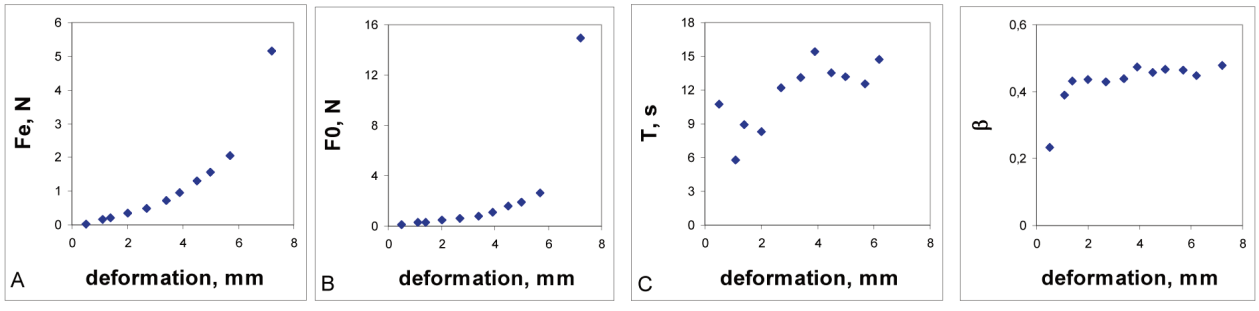

Figure 2. Rheological parameters – F_e, equilibrium force (A), F_0, amplitude (B) of exponential function, T, relaxation time (C) and β, stretched exponent (D)

The increasing forces can refer to more compacted structure, to increasing elastic modulus under loading. The increasing relaxation time ( ) can be observed because of the increased viscosity. Under the loading the macromolecular chains can be closer to each other. It is interesting, that the practically constant T at higher deformation (Figure 2/C) can show to the same increasing rate of elastic modulus and viscosity. At higher deformation the practically constant β can reflect the unchanged distribution of relaxation time.

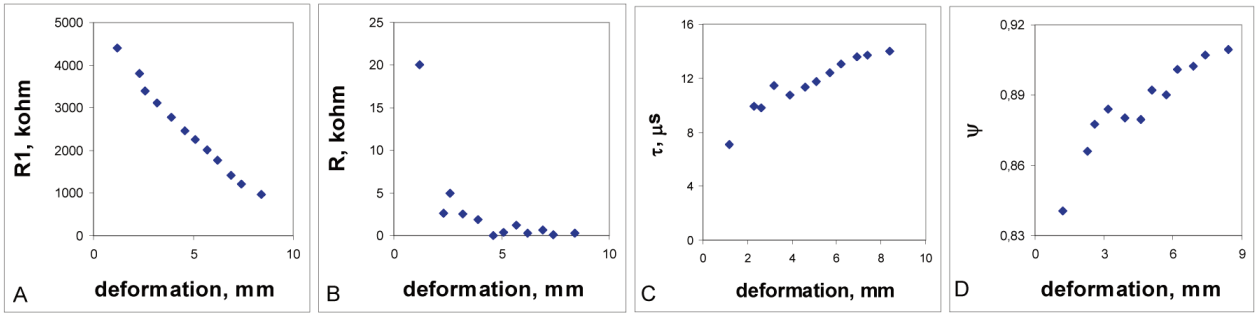

Figure 3. Electrical parameters – R_1, and R, resistances (A and B), , relaxation time (C)and ψ, exponent (D)

Resistances R and R_1 are decreasing at increasing deformations (Figure 3. A and B). Presumably the distances between the various conductive parts of macromolecular complex are reduced under the loading. This structural change can cause the decrease of resistances. Increase of τ relaxation time (Figure 3/C) can reflect the increasing viscosity and the decreasing mobility of charged groups. The increase in ψ parameter (Figure 3/D) can show the more ordered structure under loading.

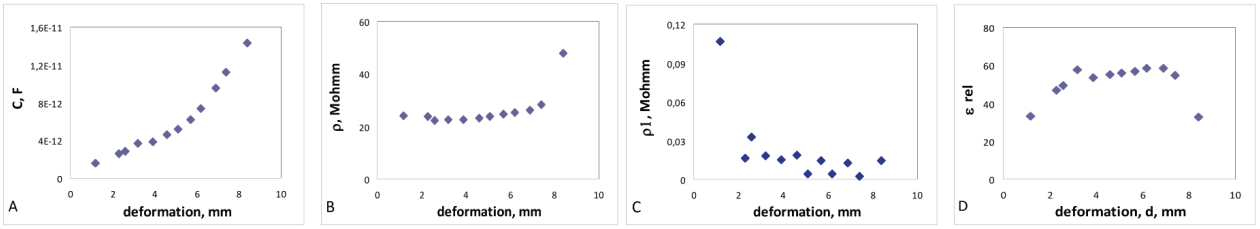

Figure 4. Electrical parameters – C capacitance (A), ρ_1, and ρ, specific resistances (B and C), ε_{rel} relative dielectric constants (D)

The capacitance of gum candies increases under increasing deformation (Figure 4/A). The specific resistance of R is also increasing under increasing load (Figure 4/B) and the specific resistance of R_1 is decreasing (Figure 4/C). The relative dielectric constant increases (Figure 4/D) at low and at high deformations, but practically constants between these two changing part. The changes of specific resistances and relative dielectric constant prove the structural changes in gum candies.

Good correlation of F_e and F_0 parameters with all electrical parameters was found.

4. Conclusion

The electrical model parameters are able to follow the structure changes under increasing deformation. The force parameters are in good correlation with all electrical model parameters.

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AIRBORNE DUST DISTRIBUTION IN TIED COWS HOUSE WITH DIFFERENT FANS OPERATION REGIME

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Abstract

Dust concentration is significant microclimate parameter in livestock buildings. Increased dust concentration affects animal health. Paper presents results of experimental study focused to the influence of fans working regime on airborne dust concentration in the barn for tied cows. Different fans rotation rates gave air flows from 23750 m^3h^{-1} to 48000 m^3h^{-1}. Measurements were conducted at four height levels, three lateral and four longitudinal sections. Consequently, 48 measuring points were selected to cover the whole space. Analysis showed that this setup gave satisfactory results. Certain regimes were recommended and rate with 37300 m^3h^{-1} was found as the most suitable.

Keywords

fan regime, ventilation, airflow velocity, microclimate, airborne dust

1. Introduction

Expression dust is defined as solid particles with a diameter up to 100 μm that are suspended in the air. Within the total (inhalable), fraction of respirable dust should be distinguished, as it contains particles with less than 5 microns in diameter [1]. There are significant because they penetrate into the deepest parts of the lungs, as opposed to larger particles that are largely retained in the upper parts of the respiratory tract. Dust in livestock buildings is primarily organic. It comes from the animal body surface (dried skin particles), bedding, dried feces and concentrated feeds [2].

The presence of increased dust concentrations causes a number of health problems. Therefore, animals productivity decreases. Employees health problems arise as well, so recommendations for allowable concentrations of dust are given according to the humans sensitivity. The most commonly accepted is value of 10 mgm-3 for total and 5 mgm^{-3} for respirable dust. In order to prevent the occurrence of long-term health problems, much more stringent limit is only 2.5 mgm^{-3} for total and 0.2 mgm^{-3} for respirable dust [3].

Optimising the heating and ventilating procedures of livestock buildings and determining the economically reasonable usage of this mechanized systems is important from the relations of costs savings. [4, 5, 6]

This paper analyzes the influence of multi regime roof fans on the concentration of particular dust fractions in order to determine the relationship between fan operation regime and dust concentration [7]. Based on this, recommendations about fan usage and settings are given.

2. Material and Methods

We investigated the effect of De Laval ventilation system Multifan with control unit STD - Manual 8 A thermostatic controller T15 - WD and DF 1300 fans. This system has a six rotation speed regimes. The fans are located below the roof, above the feeding alley. Maximum fan capacity is 48000 m^3h^{-1} (at 0 Pa), at the maximum rotation speed of 400 rpm. Measurements in the experimental cows barn are carried out at 48 measurement points (Figure 1). The dots are arranged in three sections, with 4 vertical rows in each section, and the four height levels. Measuring sections were placed in 3 distinctive parts, to 3.30 m from the front door to the feeding alley on the north side, and another 2 at the distance of 14.90 m from each other, so that the fans influence zones are covered. Vertical arrays are placed symmetrically above the feeding places and manure channels [8]. Height levels are at 50, 100, 150 and 200 cm, with the same goal as in the previous case. Concentrations of dust fraction ≤ 3 μm and ≤ 5 μm were measured. The measurement was done for five different fan operating regimes.

3. Results and Discussion

During the first series of dust concentration measurements in the experimental cow barn, fans were switched off. In those conditions, concentrations of dust particles in different parts of the room depend on natural movement of air and air humidity. Consequently, concentrations of both dust fractions (up to 3 μm and up to 5 μm) were higher compared to corresponding concentrations when roof fans were in any operating regime (Figure 2a and 3a, respectively). Concentrations were fairly uniform over the object volume, which confirms stationary state of air speed fields in the stable without forced ventilation. Some deviations that were recorded may arise as a result of cows activity, different bedding composition, distribution of concentrated feeds etc.

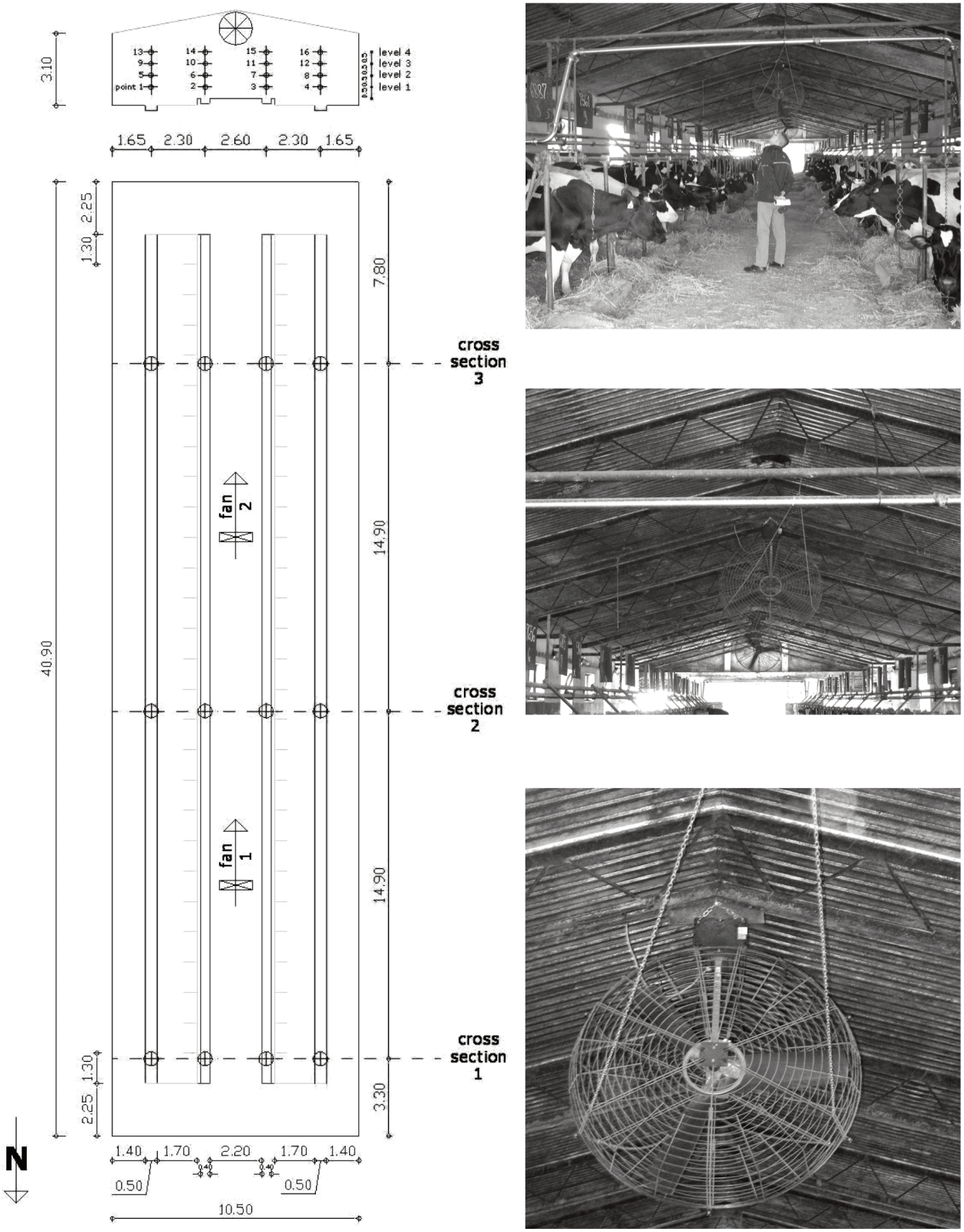

Figure 1. Building and measuring points setup (left) and inside ambient photos (right)

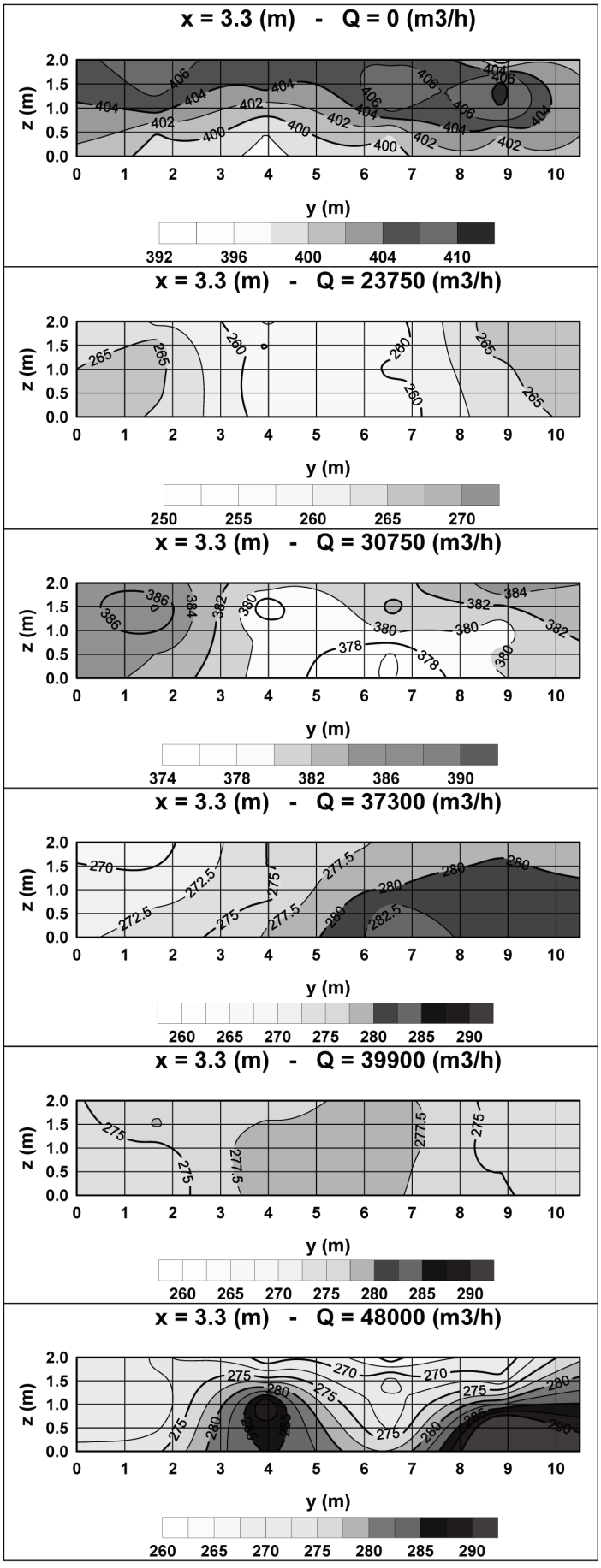

Figure 2. Distribution of 3 μm dust fraction concentrations in cross section at 3,3 m from the feeding alley entrance, under different operating regimes of roof fans

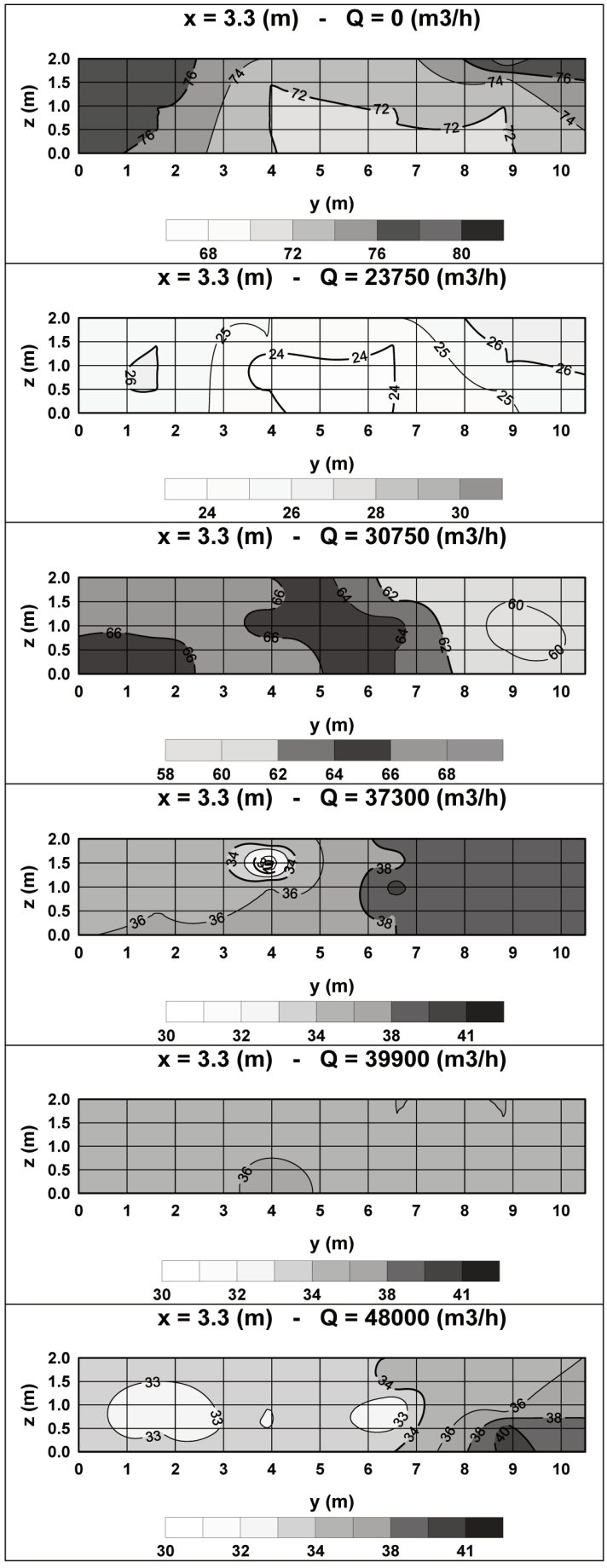

Figure 3. Distribution of 5 μm dust fraction concentrations in cross section at 3,3 m from the feeding alley entrance, under different operating regimes of roof fans

During the second series of measurements, when the fans provided nominal air flow of 23750 m^3h^{-1}, the lowest airborne dust concentration was observed, in relation to all the other operating regimes (Figure 2b and 3b). In this mode, fans provide adequate air exchange, and acceptable air flow velocity, that does not resuspend dust sediment from the floor and other surfaces. All those issues resulted in reduced airborne dust concentrations in the stable, compared to other fans operating regimes - the average concentration of dust fraction ≤ 3 μm was reduced from 403 particles·ml^{-1} (Figure 2a) to 260 particles·ml^{-1} (Figure 2b), ie. by 35%, and the concentration of dust fraction with ≤ 5 μm in diameter decreased from 72 particles·ml^{-1} (Figure 3a) to 26 particles·ml^{-1} (Figure 3b), ie. by 64%.

During the third series of measurements, that included 2nd fan operating regime with nominal flow rate of 30750 m^3h^{-1}, the highest concentrations of both dust particles fractions in the experimental facility were recorded (Figure 2c and 3c), compared to all the other regimes (excluding switched of fans). It can be expected that dust concentration would decrease after a longer fan operation and that later on reduction would continue and concentrations would stabilize at lower values.

During the fourth (Figure 2d and 3d) and fifth (Figure 2e and 3e) series of measurements, that included 3rd and 4th fan operating regime (respectively) with nominal flow rate of 37300 m^3h^{-1} and 39900 m^3h^{-1} (respectively), reduction of both dust fractions (up to 3 μm and up to 5 μm) was observed. In the facility was established a fairly uniform dust concentrations distribution. In this operating regimes, convective transport (exhaust) of dust particles exceeds its introduction into air flow as a result of sedimented particles raising from the floor and other surfaces within the facility.

During the sixth series of measurements, that includes 5th fan operating regime with maximum air flow of 48000 $m^3 \cdot h^{-1}$, the concentrations of sirborne dust particles began to rise again (Figure 2f and 3f), as a result of intensive dust resuspending from bedding, due to the increased airflow velocity in the house.

After a comparative analysis of airflow velocities and dust concentrations at different fan operating regimes, it can be concluded that, for air exchange in summer conditions, the optimal operating regimes are primarily 1st (23750 m^3h^{-1}), and then 3rd (37300 m^3h^{-1}) and 4th (39900 m^3h^{-1}). In these three cases, along with optimal limited airflow velocities, the best effects of subjective feeling were achieved by intensive body heat drawing, while achieving the lowest concentration of both dust fractions.

4. Conclusions

Based on the analysis of results of dust concentration measurements, with respect to the optimal airflow velocities requested in such buildings, it may be concluded that the best effects were achieved by the lower fan rotation speeds.

Considering reduction of airborn dust concentration, particularly favorable is 1st regime (23750 m^3h^{-1}), but also acceptable are 3rd (37300 m^3h^{-1}) and 4th (39900 m^3h^{-1}) regime. In those conditions very stable and effective dust concentration reduction was achieved, with airflow velocities that are within the optimal intervals for summer conditions (0.2 - 0.9 ms^{-1}).

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LNG BUS DEVELOPMENT

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Abstract

Having a holistic approach of the LNG fueling infrastructure network development under the PAN-LNG Project, which one is co-financed under the European Commission CEF infrastructure development program, the systematic establishment of the consumer side is also part of the work. The previously non-existing category an LNG powered city bus family are under the development.

Keywords

LNG, Bus development, PAN-LNG Project

1. Introduction

The new Trans-European Transport Network development plans feature 3 main TEN-T CORE Network, going through Hungary. It is described in the proposal COM(2011)650, published at 19.10.2011, and revised at 19.12.2011, as the Union guidelines for the development of the trans-European transport network.

The newly developed European corridor system effectively connects the Western member states with the routes coming into Hungary. It precisely shows that Hungary lies in a cargo transport and logistic centre, where the most important Western, Northern and Southern sea ports are the gates to the corridors leading to it. This is the reason why so many logistics centres have settled in Hungary in the past decade. For building up the alternative fuelling infrastructure in Europe, as allowing to evaluate the main goals of the communication COM(2013) 17 in 24.01.2013 by the European Parliament and Council about reducing the dependency of the oil in the transport sector, the busiest roads, the most important CORE Networks have to be prioritized.

The PAN-LNG project aims to implement the first five road LNG & LCNG Liquified and Compressed Natural Gas vehicle filling station, based on liquefied natural gas tank, where in addition to serving vehicles with LNG tanks, the compressed natural gas (CNG) vehicles with can also be supplied high filling capacity, to serve heavy and light duty vehicles) vehicle filling stations, equipped with liquefied natural gas tank as well as the safe fuel supply of these on major European road transport lines, the Mediterranean and Orient-East-Med corridors of the TEN-T core network and the Hungarian territory along the Rhine-Danube corridor.

By the installation of LNG filling stations on the corridors in Hungary, the PAN-LNG Project significantly increases the value of the role the other Europe-wide ongoing projects. Based on the Connecting European Facility co-financed projects, there are 33 known individual projects, delivering new LNG, as well CNG infrastructures. The almost 0,4 billion € investment, of which just over 0,2 billion € is a European co-finance, will deliver at least 180 new LNG filling point (more than the today existing figure) and roughly 140 CNG points on our common roads.

It is more than impressive how these figures are improving the availability of the LNG fuel. However, if we consider on the task of sending the diesel to retire as laid down in the White Paper (COM (2011) 144 White Paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system), need at least 10-fold as many station in the EU. And this story isn't only an investment needs of 3 billion € in total only for completing the LNG infrastructure to available for everyone. From one side, the LNG vehicles need to be in action anywhere in Europe and needs to be driven without having any extra trip for refuel them, because that destroy the acceptance of the vehicle operators. LNG filling station investment needs return of capital, understand it; needs customer, which securing the daily consumption. The responsibility of the vehicle manufacturers equal at the CNG and the LNG case, need to make the infrastructure network profitable [1].

2. Today's Needs

Till the speed of the NGV economy tune up, needs to go ahead with the LNG infrastructure network development. After the corridors, at the cities and at the main routes need to be equipped. Therefor need business case for the infrastructure developers, ergo need to be able let finance their 0,5-1,5 million € high investments according to a strict CBA, which must be acceptable for banks as well. And mostly here the trucking industry is a bit difficult. If the LNG powered trucking fleet to be established, not owned by the station developer, then the consumption is hardly predictable and even weaker chance stay to secure a long-term sales volume. One 40 t truck should consume daily 100-120 kg of LNG, quite exact number, however the problem is, that long-haulage means, but also the middle range missions are not refuelling always at the same place [2].

Needs to establish a constant base consumption to run the business, but it is essential also from the side of the gas-technology. Thinking on that, two solutions are popping up. Extending the target of the sales by the CNG vehicles can help a bit through the so-called L-CNG filling-station technology. Could

be improved the economy, if there a certain number of lorries, locally used light- or heavy-duty vehicles can put into the consumer heap. That is however not for ever can secure the consumer side, because if the business is running, then a newcomer can pillage the profit. The situation is a bit different if such a professional consumer is providing the base load for the LNG station, like a public transport service. Buses are running on a same route, consuming predictable quantity even for years ahead. Also, the growth of the fleet can be predicted, if the PT-company is satisfied and if not, the whole fleet have been changed for the first moment, but the changes are coming naturally as the vehicles arriving to a certain lifetime, when they get renewed [3].

The good thing in the bus fleet, that it is exist at every major city, so based on that, every important location where any concentration of industry exists, so bigger good transport needs take place, there for sure has got PT needs and a bus fleet, which can be served by LNG. And based on that, can find the way to establish a useful network of LNG fuelling stations.

3. Having LNG & LCNG station instead of CNG is a newly available position for decision

There are roughly 800 thousand buses in the EU to be changed from diesel to environment friendly alternatives, where at least for two-third no any other fuel could pop up than the methane. Any newcomer fleet operator now dreaming on purchase a CNG bus fleet, already can decide, having gas from the pipe, placing compressor stations or let to establish an L-CNG station. I would highly recommend the second option, because of many reasons, but first of all, the accessibility for the LNG fuel too.

If the L-CNG station has got not only CNG dispenser, but equipped with LNG dispenser too, and a submerge pump which supply the liquefied gas into, then station is ready for fill the LNG vehicles too. Here to be cleared, the flow rate of the LNG at the dispensers can go up to 150 l/min, that refill theoretically in 7 minutes the IVECO for over 1500 kilometres range. That is roughly 500 kg of gas, in case of CNG this quantity would take roughly 20 minutes at the station of Miskolc, if the vehicle standing alone, but even only through the NGV2 nozzle system [4].

For those, who are new to establish a station for refuel a CNG bus fleet, the L-CNG system versus the old CNG compressor technology can compare in these (Table 1.).

If the filling station technology to be selected is clear, and it is based on the LNG, then comes a question:

– Why not an LNG bus instead of CNG?

And the simple answer is:

– Because it is hardly existing in Europe.

4. The sense to produce an LNG-powered bus instead of ZNG-powered one

Let's suppose first, the LNG refuelling possibility exist with equal chance to a compressor station. If the selection based on the principles, Table 2 shows some of the main points.

Beside of so many positive arguments, there are some negative ones at the CNG buses. Mostly concerns around the bodywork.

If a bus bodybuilder has a product for diesel, to redesign it to an LNG version is significantly simpler then construct a CNG version. Modify the body structure at CNG version for holding the tubes on the roof is not simple. Not only supporting the weight increase and avoid any tendency for frame cracking somewhere else is complicated, but the vehicle driving characteristics are also deeply modified, since the leverage from the vehicle natural momentum are very long. It effects the suspension characteristics and the brake force distributions. Since the rollover protection of the vehicle, effected by the carried weights on the top, serious modifications need by the constructers and new rollover tests also must be done.

If the designers would like to develop a bus type, which has a dedicated city version and beside of, wish to implement an intercity arrangement, the effects on the drag force makes the CNG hunch an important barrier, or at least an undesirable parasitic. This increase in highness can be also strange at a low tunnel.

The weight increase at CNG versions compare to the diesel is also on the negative side of the arguments. The almost 500 kg to the 1,2 tonnes surplus exist on the market, what makes the vehicle thirstier. But also, less passenger can host, according to the registration [4].

Compare to the CNG versions, LNG tank is lighter, the structure of the vehicle need no improvement, no newly designed suspension need. No increase in dimension and the passenger capacity is also just with 2-3 people less than a diesel one. Without excrescence on the roof, the LNG vehicle has no drag increase, ergo overconsumption. This is an important point at tempo 100 for instance.

5. Assume all the above-mentioned reasons, there is a need for LNG bus on the market

As developing the PAN-LNG Project, establish 6 LNG filling-stations in row in Hungary with the acceptance of following a few dozens of the similar investments, strongly looking for customers. To catch them, need some good vehicle offer. One of the best option can be a good and reliable bus. In Hungary and at most of the post-communist countries, the brand name of Ikarus means a really reliable bus. Many countries are still using their 30+ year old buses, and renew them. Even in Germany can find some veterans with 50 years, however they are not serving anymore just for shows. In the eighties, Ikarus was the biggest bus producer on the world, the 200-series and the later introduced low-floor 400-series were built in over 250 thousand pieces. Above 100 thousand of them are still on the road. For sure, it was possible under the socialist Comecon regime, which was far not a free-competition market, so after the revolution, the market and the production collapsed from the 14 thousand in a peak, to a level of 3, if not a 2-digit quantity per a year [5].

To develop a prototype with the aim of producing the new model, without an existing large-scale production is something, what also challenging. From the other hand, this can also revitalize the company, which has a lot of good potential. The decision made, agreed on the cooperation between the owner of the company and the investor of the LNG-station network, Pannon Fuel Kft. Based on that, the actual diesel type will be refurbished to an LNG one.

For the new engine had to redesign the supporting frame structure, finding a better angle, a more durable structure. But not only this were changed compare to the basis version. The supplier ZF modified the front axle compare to the previous design, and for this had to redesign the area of the connections. Based on the experiences, the frame structure designers were improved the inertia of the used stainless-steel profile on the lower longitudinal frame section, making the frame resistant to any brittle fracture, what is actually a weak side at most of the stainless-steel framed buses on the todays market.

It was clear from the beginning, that the position of the fuel tank will skip the small window on the backside, which request a new panel design. The designers were also newly furnishing the inside of the passenger area, finding some more space not only because of the out falling of the two diesel tanks. Despite the more space inside, the reduced spacious back front made the vehicle shorter to 12,5 m instead of the 12,7 m from the diesel

version. The available space supporting the unique large passenger capacity. In figures: 30 seating plus 78 standing passengers can get in, 12 more as at the new Citaro NGT. For a future intercity purpose, we have a design for elevated flor behind the second door and the third door is falling out. This way can we reach 49 seating places in the 12,5 meters frame [6].

Table 1. Comparison of L-CNG and CNG technologies

Topic	**L-CNG technology**	**CNG technology**
Choosing a location	Needs only space where the safety distances are secured, only small amount of electric power	Beside of space and safety distances, needs high pressure and capacity gas pipeline, enormous electric grid connection (mostly new transformer)
LNG source	If an importing terminal within 500 km it is fine, if within 1000 km, can live with, only small extra cost, >1000 km let think on another LNG source to be found	Don't need to have it, but if it is existing, secure the gas supply for the gas grid
Gas price includes charges	LNG over production makes the gas cheap for long, that makes good business perspective for all of the LNG consumers. Strongly influenced by European trading level	LNG pricing are treated the prices for the pipe exporters, like Russia, this is however seeming well, where the competition to LNG exist, at those European markets, where the transporting routes are topping up the LNG prices, there the pipe gas is also more expensive. The capacity fees at the connection points are affecting the gas price and the national distribution fees can treat the attractivity of the CNG. Strongly influenced by the national trading and politically based regulatory issues
Electric consumption	Max. 1/10 of the CNG	Min. 10x of the L-CNG
Having redundancy	Install 1 high pressure pump + 1 vaporizer	At least N+1 compressor to install
Increase the filling capacity by 1500 Nm3/h	Install 1 high pressure pump + 1 vaporizer	Install at least 2 compressors and extend the gas grid and electric grid capacity, if it is possible
Can have barriers to establish a capacity above 1000 Nm3/h	No	Yes, upon the capacity of gas grid, less often at the e-grid
Cost to establish a right station for a fleet of 50-100 buses	Including LNG vehicle filling, budget 1,2 million euros	Budget 1,5 million euros
Cost of doubling the size of the fleet	Budget altogether 0,2 million euros, no barriers	Budget of 1 million euros, if possible
Timeframe to deliver a station from scratch	~ 5-7 months	~ 5-18 months
Demand for maintenance	Less intensive	More intensive
Designed lifelong	>20 years	>20 years
Inert gas in the fuel	Depends on liquefier technology, but higher than 1 % Nitrogen is rarely	Depends on the composition of gas sources, easily can go even up to the range of 15 %
Existent of longer hydrocarbons	C2-C4 possible	up to C6 is commonly exist
Energy content, indicative Wobbe index	54-55,5 MJ/kg	40-49 MJ/kg
Business prospect to sell fuel for the public	Important role and have a big sales potential in LNG, but CNG exist as well	Important role for those regions, where public CNG stations are rarely available

Table 2. Comparison of LNG and CNG technologies

Topic	LNG bus	CNG bus
Driveline	Same	Same
Pressure reducer	For LNG version (up to 25 bar)	For 200 bar CNG
Gas tank	Cryogenic for LNG	High pressure for CNG
Size of the tank	310-460 l	910-1820 l (MB offers 4-6 pc for Solo, 5-8 pc for Articulated)
Empty weight of the tank	250 – 350 kg	280 – 560 kg + structure ~70 kg
Gas capacity	131 – 196 kg	130 – 260 kg
Compliance with body stability UN ECE-R66.02 regulation	Same structure as diesel version	Need improvement compare to the diesel version
Brake and suspension	Same as diesel	Need to be adjust compare to diesel
Effect on the frontal area	No	Significant A modification, but also different on c_w
Intercity and highway applicability	Yes	The increased C_w makes barriers
Average overweight to diesel	~150 kg	485 kg (MB) - ~1200 kg (MAN)
Average loss in pass. capacity	3 people	8 people
Energy efficiency	Minor disadvantage on the weight increase	Higher disadvantage on the weight increase as well on the drag force
Different in highness to diesel	None	Up to 45 cm
Average time of a refuel at a well-established Station	3 min	10 min, if filled alone
Needs of personnel training	Yes	Yes

The selected engine for the solo Ikarus is the ISLG9, an 8,9 litre, 224/302 kW/LE (2100/min) Euro VI homologated one, with a peak 1167 Nm torque, with a flat curve between 1300-1600/min. Nice, that the engine has constantly over 87 % of the maximum torque available between 1000 and 2100/min RPM, means above 1000 Nm are constantly available from the slightly increased idol to the peak point of the power curve. This engine family has got in the top version 320 horsepower and +200 Nm torque. That is pretty good for the next coming articulated city version. But also, can serve an up to 49+1 seating capacity, intercity solo vehicle, which one keeps within our next plans. Not the engine is the only gas consumer, but the heating system for the passengers are also equipped with gas-powered heater. As opposed to others, we didn't accept an alternative fuelled vehicle with a diesel-powered heater, however that system inclusive with its extra diesel tank would cost far less, than the gas heater. The engine is paired with the ZF Ecolife 6AP gearbox. In Europe the widely applicated modern gearbox also with the TopoDyn function can be ordered, as a customer option.

There was a strategical decision at the end, which producer should be preferred for the LNG tank. As having different objectives, like:

- keeping the most possible share of the European production,
- having the lowest cost for the bus, to keep it as good in competitiveness as possible,
- destroy the producer hegemony, to make free market situation in Europe for finally, in the favour of the customers, fleet owners.

At the time of the project start there were only one known producer with the R110 certificate for LNG bottle in Europe, however that was not for buses, just for trucks homologated. Finally decided, to import LNG tank from China, where the production is far bigger for these bottles, then in the whole rest of the world. Just to not, the LNG vehicle market in China comes close to 100.000 unit (!) this year, as reports are showing it.

The selected size of the first solo bus keeps a rounded 150 kg of gas, good for up to two days in a city mission. For customer preference, or for the articulated version this can be exceed the 200 kg mark with the today available tubes.

6. Conclusions

The result of our tank selection is finally coming serious, compare to another offer from Europe, the price advantage reaches the 3 % mark of the total vehicle. If we compare to our LNG bottle to a set of a CNG cylinders, we can find an advantage level of 3-4 % a price of a solo CNG bus. If we consider the price disadvantages for the customers, what we have at CNG buses compare to the diesel ones, we can realize 20 + percent. According to our analyses, this is a result from market pricing mechanism, the products cost as much, as the customer intend to pay for. Not an equalized possibility for the NG vehicle penetration growth and not supporting sufficiently the infrastructure developers.

The proto vehicle is already finalized, the new type approval is on the way. The orderbook is going to be open soon and up on

the serious interests from different markets beside of the local one, the production capacity can be established up to the 3000 per annum level.

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EVALUATION OF OHMIC HEATING DESIGN USING THERMOVISION

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Abstract

Ohmic heating is a promising technology for economic cooking. Electrical energy is directly affecting foodstuff and treatment starts inside. Viennese type smoked pork sausages were used in the experiment. Sausages were treated with and without immersion into NaCl solution. Two sausages were treated parallel at the same time in 3 replicates. Three levels of voltage were applied (50 V, 125 V and 200 V). Thermovision data was confirmed using infrared thermometer and compared to finite element simulation results. Both equipments had ±2% accuracy. Middle level of 125 V was found to be optimal for cooking. Highest surface temperature reached expected 75 °C rapidly.

Keywords

electrical engineering, Joule heating, cooking, Viennese sausage, thermal imaging

1. Introduction

Heat treatments are always in focus of attention, like pasteurization and sterilization. Ohmic heating, also called as Joule heating, is popular since it is fast and economic method without transfer medium. Jaeger et al. [1] investigated the literature and found that products of 0.1 – 10 S/m electrical conductivity can always be treated successfully with this technique. Mainly alternate current is used in order to prevent electrochemical and electrolytic effects. The field strength is typically in the range of 3.5 – 40 V/cm for meats. Highest values were observed for beef [2]. It was found that ground beef was cooked faster, final product was firmer, color was more homogeneous and volume reduction decreased compared to conventional technology. Ohmic cooking was successfully used to prepare meat balls [3]. The total mesophilic aerobic bacteria number decreased significantly, yeast and mould fall to undetectable levels using 15.46 V/cm voltage gradient. Since ohmic heating did not eliminate Listeria monocytogenes from meat ball samples, authors suggest application of this technology in combination with other methods. Engchuan et al. [4] cooked meat balls of ∅2.8 cm with immersion into NaCl solution, where salt content was adjusted to 1.5% of pork weight. The heating was designed to reach 80 °C temperature. According to the results, Sukprasert's semi-empirical temperature prediction model was improved. Scanning electron microscopy of the products revealed that significant difference is visible between conventional and ohmic heated meat ball texture. Ohmic cooking made more homogeneous microstructure with small pores. Raw beef muscle treated with additional 3% salt was cooked with 100 V voltage up to 72 °C and 95 °C target temperature by Zell et al. [5]. This treatment was found to be at least 7 fold faster than conventional heating, but its major advantage was the reduced cooking loss. All other quality parameters, such as sensory attributes, textural properties and color, were comparable to that of the traditional method. Zell et al. [6] also cooked turkey meat with this technology. The meat was injected with 3% salt solution up to 130% of initial weight. Voltage was adjusted to 100 V and treatment took 8 min. Significant difference was observed between cooking loss of traditional, ohmic slow and rapid cooking. It was concluded that products treated with ohmic heating were preferred over conventional, but kinetics must be optimized for best sensory values. According to the literature, raw meat samples were always treated with salt solution of different concentration before ohmic cooking. Ready to eat food products are unlikely to require pretreatment with salt solution due to higher salt content and prevention of change of sensory attributes. The objective of the presented work was to investigate different setups of ohmic heating by means of non contact temperature monitoring. Effects of electrical parameters, electrode configuration and immersion into NaCl solution were evaluated.

2. Materials And Methods

Materials

Viennese type smoked pork sausages were acquired in retail store. The packages of 160 g contained 6 pieces with the geometry of ∅2.8 cm and 17 cm length. Measurements were performed with two pieces in parallel and three replicates. According to the assumed salt content of sausages, three simulations were performed. Average salt content of the product was 2.5%, but changes can occur due to treatment and immersion into NaCl solution. Properties were adjusted in simulation according to Choi et al. [7] (Table 1).

Methods

Adjustable power supply (model TD 1001, TRAKIS) of 230/0-240 V and 1000 VA was applied to provide required electricity.

Multimeters measured voltage (VC2020, Voltcraft, Germany) and current (MY-64, Mastech, China). Electric circuit is introduced in the following figure (Figure 1). Three voltage levels were adjusted as 50, 125 and 200 V resulting in 3.33, 8.33 and 13.33 V/cm gradient.

Table 1. Electrical properties of sausages used in simulation

Property	Low	Medium	High
Salt content	1.25%	2.5%	5%
Thermal conductivity, W/mK	0.999	0.999	0.999
Electric conductivity, S/m	1.50	2.79	5.11
Density, kg/m^3	1023	1031.34	1048
Specific heat, J/kgK	3279.08	3239.42	3160.10

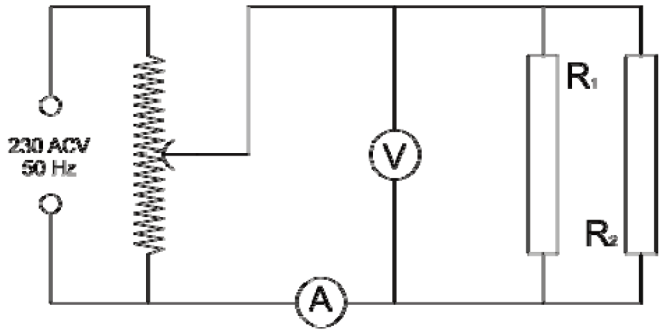

Figure 1. Electric circuit of the measurement

The vision system consisted of a thermal imaging instrument (MobIR®M4, Wuhan Guide Infrared Technology Co., China) operating in the spectral range of 8-14 μm with ±2% accuracy. Captured data were evaluated using bundled IR Analyzer software (Wuhan Guide Infrared Technology Co., China).

Besides still image acquisition, USB video grabber (MT4169, Media-Tech) was used to capture video of the treatment and read temperature values more frequently.

COMSOL® Multiphysics simulation software (5.3, COMSOL Inc., USA) was used to perform finite element modeling. Parameter values, such as density and specific heat of ingredients, were estimated according to Choi et al. [7]. Models calculated electromagnetic field and temperature data in sausage samples. Theoretical values were compared to experimental readings.

Experimental data was collected, preprocessed and evaluated in Excel® (Microsoft Inc., USA) and R (R Foundation for Statistical Computing, Austria) software.

3. Results and Discussion

Geometry model of sausages was made of a cylinder and two closing semi-spheres. Electrodes of cone shape were inserted at the top of the spherical ends (Figure 2). Simulations were performed on a workstation of Intel I7-3820 @ 3600 GHz CPU and 64 GB RAM in the laboratory of University of Salerno, Italy.

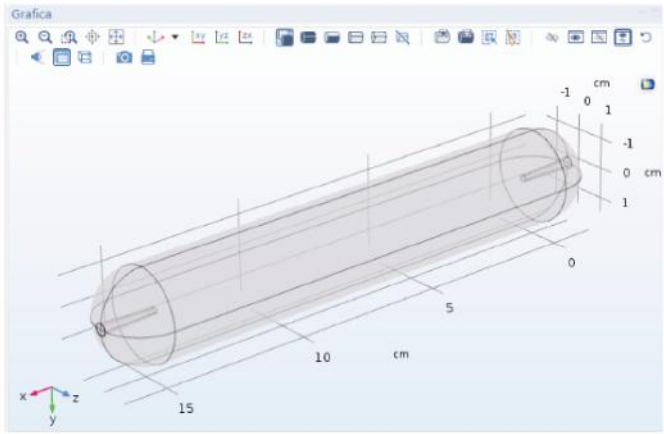

Figure 2. Shape model of sausages in COMSOL 5.3

Simulation results were in agreement with observed temperature distribution. The middle axis between the two electrodes was heated first and temperature increased in the cylindrical part (Figure 3). Simulation results shown that increasing salt content accelerate ohmic cooking. Immersion half way into 10% NaCl solution helped only to heat up transfer

medium faster. In that case, sausages were found to have the same surface temperature as surrounding medium. Thermovision was unable to look inside salt solution, therefore manual IR temperature readings were collected on sausage surface above liquid level in that experiment. The primary factor affecting ohmic cooking was the applied voltage. It was observed that temperature and current increased parallel at the beginning and current reached the maximum when meat burnt around electrodes. Surface temperature increased for a while with decreasing current after maximum. Burnt meat is likely to isolate electrode and prevent current flow. The temperature increased with 60.5, 87.6 and 101.5 °C for 50, 125 and 200 V, respectively.

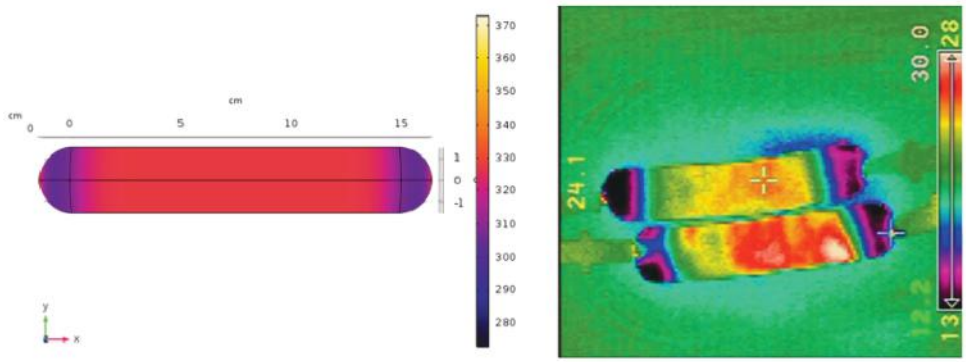

Figure 3. Heat distribution on surface by simulation (left) and thermovision (right)

Temperature and current data for 125 V are presented in Figure 4. The maximum current was reached at 22 s followed by the maximum temperature at 28 s. The observed shift between curves and their shape indicate that both electromagnetic field and internal heat transfer cooked sausages.

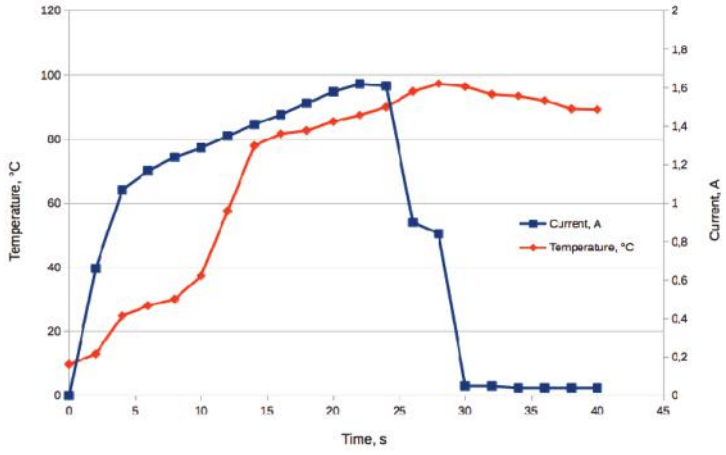

Figure 4. Temperature and current readings for treatment with 125 V

Surface temperature simulation shown a cold ring on the semi-spheres near the end of sausages and it was also observed on thermal images (Figure 3). The simulation of electromagnetic field confirmed that it has the minimum strength at that locations (Figure 5). The electromagnetic field was found to be homogeneous between electrodes and decrease rapidly at tip cap.

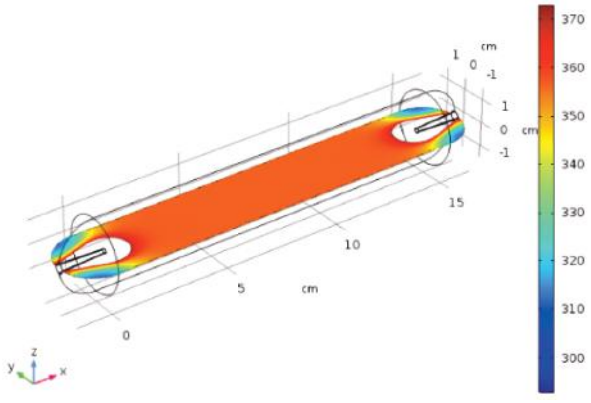

Figure 5. Simulation result of the electromagnetic field

According to the simulation result and observed surface temperature distribution, the cold point of the product is on the surface and close to electrodes far from the opposite one. Ohmic heating treatment time shall include the time required for heat transfer to cook coldest regions as well.

4. Conclusions

Pilot plant was assembled in order to investigate ohmic heating of Viennese type pork sausages. Compared to literature, ready to eat food product does not seem to require additional treatment to increase salt content or immersion into salt solution. The source electricity of 125 V was able to cook sausages rapidly and surface temperature increased with 87.6 °C during experiment. Lower level of 50 V was found to be slower and less practical. On the other hand, high level of 200 V was too rapid and burnt meat around electrodes quickly without useful cooking. Theoretical finite element simulation was in agreement with observed experimental readings. Temperature was observed to increase primarily in the cylindrical part between electrodes and the cold point was found on the surface of semi-spheres at the ends. Ohmic heating is a promising technology to cook homogeneous sausages rapidly and more economically. The treatment requires optimization in order to cook cold regions taking care of microbial safety and control source voltage to keep joule heating without burning the product.

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PRESSURE REGULATION IN PNEUMATIC TRACTOR TYRES

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Abstract

Work on tyre pressure regulators has hitherto paid little attention to energy consumption. Energy use depends on how frequently and over how wide a range the pressure is changed. Larger tyres also require more energy for inflation. Consequently, care must be taken in choosing the tyre pressure and the route taken, avoiding inappropriate types of road. Since the physical properties of the soil are partially dependent on the weather, current soil condition on terrain routes should be properly considered when setting the tyre pressure.

Keywords

tyre pressure regulator, tyre load capacity, contact surface, specific ground pressure, radial

1. Introduction

Many agricultural machinery manufacturers now offer tyre pressure regulators for their products. A pressure regulator inflates tyres to pre-set pressures either at the press of a button or automatically, using GPS signals. None of these systems, however, take account of current road conditions, for example, after sustained rain or drought. The best basis for setting tyre pressures is the data provided by the manufacturer. Tyre catalogues carry graphs of tyre load capacity against pressure at various travel speeds, from which the appropriate pressure may be read. At present, the effect of road conditions is considered only in distinguishing between rigid track (travel on a public road) and deforming track (on terrain). On a rigid track, the tyre pressure is set as high as possible so as to reduce rolling resistance and prevent tyre wear. This is comparable to tyre pressure optimisation systems for passenger cars, involving tyre pressure monitors or automatic pressure regulation [1]. On a deforming track, the aim is to reduce the inflation pressure as far as possible, which reduces the specific ground pressure and thus the energy required for travel [2, 3]. Furthermore, appropriate tyre pressure improves tractive efficiency [4]. The benefits of the tyre pressure regulator are thus realised in the form of fuel savings. Little is said, however, about the energy consumption of the pressure regulator. Clearly, the higher the frequency and the wider the range of tyre pressure changes, the less energy savings there will be. Furthermore, the larger the tyre, the more energy is required to inflate it.

Since the relation between ground pressure and sinkage is described by a saturation curve, reducing the tyre pressure to its lowest setting is not absolutely necessary. After a certain point, the increase in contact area with decreasing pressure is so small as to achieve no significant improvement in soil compaction and tractive force. Re-inflation of the tyre, however, requires a substantial amount of energy.

Our aim is therefore to minimise the pressure difference in the tyres when travelling on roads and on terrain, by taking account of current soil conditions.

Theoretical energy requirement for change of tyre pressure.

We determine the theoretical energy requirement of a 710/75 R42 tyre, assuming constant temperature and tyre volume.

Profile width: B = 71 cm
Profile height: H = 53.3 cm
Tyre diameter: D = 213.3 cm
Tyre air volume:

$$V = \left(\frac{B}{2}\cdot\frac{H}{2}\cdot\pi\right)\cdot(D-H)\cdot\pi = \left(\frac{0.71}{2}\cdot\frac{0.533}{2}\cdot\pi\right)\cdot(2.133-0.533)\cdot\pi = 1.49\,m^3 \qquad (1)$$

Pressure range applicable to tyre (from catalogue): 0.5–1.8 bar
Tyre energy at lowest pressure:

$$E_1 = p_1 \cdot V = 0.5\cdot 10^5 \cdot 1.49 = 74500J$$

Tyre energy at highest pressure:

$$E_2 = p_2 \cdot V = 1.8\cdot 10^5 \cdot 1.49 = 268200J$$

Thus, energy required for inflation:

$$\Delta E = E_2 - E_1 = 268\,200 - 74\,500 = 193\,700\,J = 193.7\,kJ$$

This is the energy used for a cycle of one inflation and one deflation. For an axle with two such tyres, the energy required for a cycle involving a change in pressure of 1 bar is 298 kJ. This corresponds to the energy provided by 7 g of diesel fuel. In practice, the energy expended is higher than this theoretical value because it includes losses in the inflation system.

2. Determination of the load capacity of the tyre

The load capacity of the tyre is determined, where possible, from the manufacturer's catalogue. Otherwise, it may be calculated

from a knowledge of the tyre dimensions and operating circumstances, using the following formula [5]:

$$T = \left[C \cdot (B \cdot D) + \alpha \cdot (B \cdot D)^n\right] \cdot C_v \cdot C_p \tag{2}$$

Speed factor:

$$C_v = 1.72 \cdot v^{-0.23} \tag{3}$$

Tyre pressure factor:

$$C_p = L \cdot p^m \tag{4}$$

T - tyre load capacity, [kg]
B - tyre width, [m]
D - tyre diameter, [m]
c_v- speed factor, [-]
c_p- tyre pressure factor, [-]
p - tyre pressure, [bar].

Table 1. Values of variables

Variable	Radial tyre	Diagonal tyre
m	0.46	0.55
L	0.78	0.78
n	2.00	2.00
α	650.00	500.00
C	4500.00	3800.00

3. Determination of specific ground pressure under tyre

After obtaining the load capacity of the tyre, the next step is to determine the specific ground pressure under the tyre, for which we also use the dimensions and operating parameters of the tyre. The empirical formula used does not apply to deforming soil, but minor sinkage only slightly increases the contact area, and so – if z/D ≤ 0.05 – the following formula may be used to a good approximation [6]:

$$\sigma_R = T^{0.15} \cdot (B \cdot D)^{-0.2} \cdot p^{0.6} \cdot 33.3 \tag{5}$$

In addition to the tyre load capacity and the ground pressure under the tyre, we need the value of a quantity that characterises the current condition of the soil from which we may calculate its bearing capacity. The Saakyan formula, which relates specific ground pressure to soil condition, may be used to obtain the soil bearing factor.

$$\sigma_R = k \cdot \left(\frac{z}{d_e}\right)^{n_1} \rightarrow k = \sigma_R \cdot \left(\frac{d_e}{z}\right)^{n_1} \tag{6}$$

where:
k soil bearing factor, [Pa]
z soil deformation, [cm]
d_e equivalent pressure plate diameter, [cm]
n_1 soil dependent constant (for loamy sand soil: 0.8) [-].

The equivalent diameter is calculated from the contact area, which is either measured or calculated, the latter involving the empirical relation:

$$A = 2.26 \cdot (B \cdot D)^{0.5} \cdot \Delta r_R \tag{7}$$

where:
Δr_R tyre deformation, [cm]
A contact area, [cm^2].

The most convenient method of determining tyre deflection or deformation is direct measurement, allowing contact area to be obtained using Equation (7). Tyre deformation may also be calculated, however, by the empirical [7]:

$$\Delta r_R = T^{0.835} \cdot (B \cdot D)^{-0.3} \cdot p^{-0.33} \cdot 10^{-2} \tag{8}$$

The equivalent diameter is:

$$d_e = \sqrt{\frac{4 \cdot A}{\pi}} \tag{9}$$

The ratio z/D is the depth to which the wheel has sunk into the soil relative to its diameter. A high z/D value thus means that the wheel has sunk deep into the soil. This implies that, for the same specific ground pressure, wheel sinkage decreases with increasing soil bearing factor. This gives the name of the factor k. Conversely, for the same sinkage, specific ground pressure increases with k, meaning that the soil bears a greater load.

Therefore, the soil bearing factor must be set to the highest possible value by adjusting σ and d_e, or rather by setting tyre pressure and load, because σ and d_e are also functions of tyre pressure. This is possible because the bearing capacity of a soil is not simply an inherent property but a function of the interaction, i.e. the size of the contact area.

These relations allow tyre load capacity to be plotted against tyre pressure:

Figure 1 shows the load capacity of a 710/75 R42 tyre against tyre inflation pressure, calculated using Equation (2), at travel speeds of 12, 24 and 36 km/h. The pressure range must lie within the working range of the tyre. There is no sense in investigating outside this range, because at higher or lower pressures, the tyre would fail within a short time. The variation of load capacity is approximately proportional to tyre pressure. Increasing speed severely constraints maximum load. For example, for a pressure of 3 bar, the load capacity at 36 km/h is only 78% of that at 12 km/h.

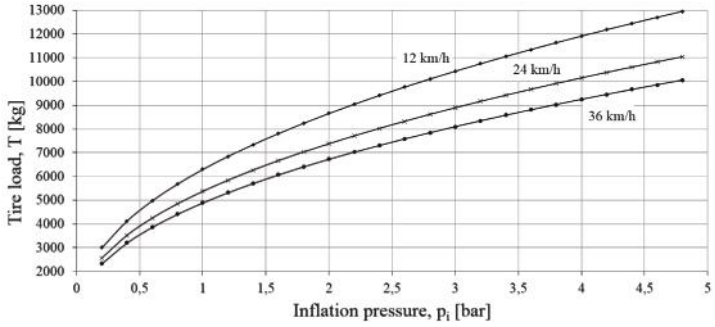

Figure 1. Load capacity of 710/75 R42 tyre at various speeds

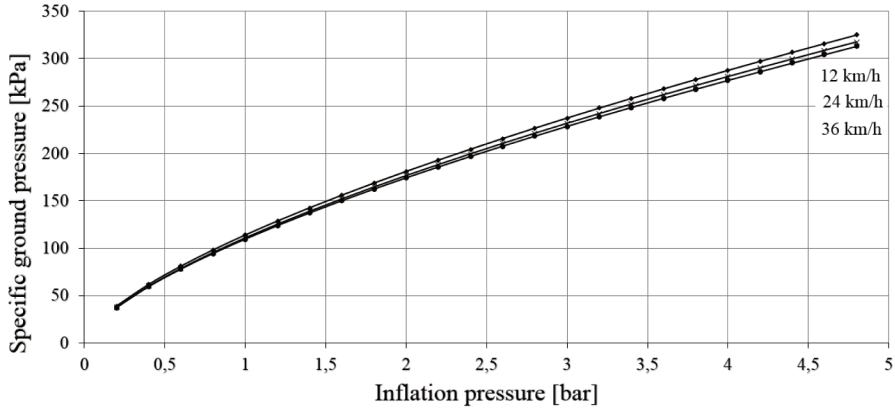

Figure 2. Specific ground pressure at maximum load.

Figure 2 shows the specific ground pressure calculated using Equation (5) at the loads calculated above, again for speeds of 12, 24 and 36 km/h. As for load, the ground pressure curve is linear to a good approximation, but the speed has much less effect. At 3 bar, the difference is approximately 4%. The main effect is that of change of load, because in Equation (5), the speed has no direct presence. Since field measurements may have errors of more than 5%, this change is difficult to detect.

Figure 3 shows the soil bearing factor against soil deformation, using the specific ground pressure values. The bearing factor clearly varies more steeply in the 0–4.8 cm range than in the 7.8–12 cm range.

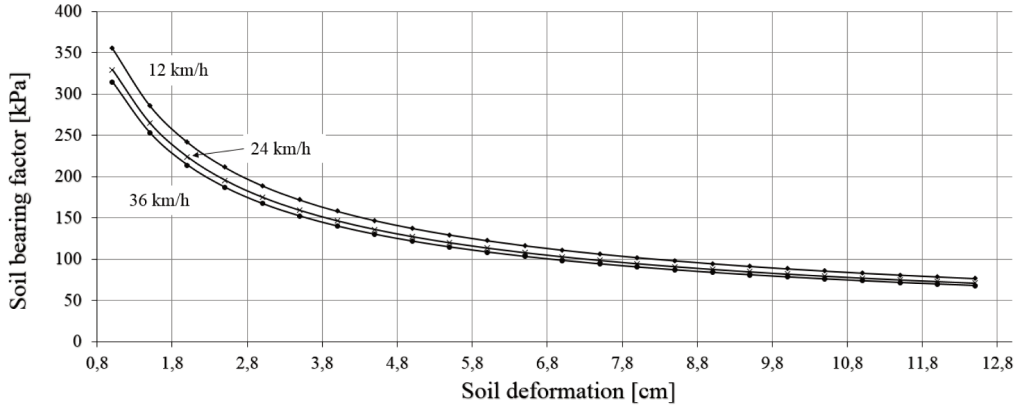

Figure 3. Soil bearing factor as a function of soil deformation for a 710/75 R42 tyre.

4. Conclusions

Using known tyre parameters and operational parameters, and for specific speeds, the graph of tyre pressure vs. tyre load may be constructed from Equation (2), and that of tyre pressure vs. specific ground pressure from Equation (5).

1. From these graphs, we can read off the maximum load from a given tyre pressure or the tyre pressure applicable for a given load, at the relevant speed. The graph thus tells us the required change in pressure (Figure 1).
2. Knowing the maximum ground pressure for the soil, we can obtain the corresponding tyre pressure (Figure 2). This also tells us the required pressure change.
3. The soil bearing capacity may be obtained from the rut depth using Figure 3.

With regular data collection, further comparisons and analyses could be made from the bearing factor. Possible examples are the comparison of bearing factor values for different fields, the investigation of sensitivity of bearing factors to changes in moisture content in specific fields, and the determination of the relationship between tyre pressure and bearing factor. Given the wide scatter of soil physical characteristics and the diversity of operational circumstances, individual measurements for each field are required to determine the parameters precisely.

Knowing these, it is possible to ensure that the tyre pressure regulator is always set to the appropriate level. The savings offered by the pressure regulator, however, can to some extent be wasted by overuse, and so we must also control the frequency and magnitude of changes.

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