Acta Scientific Applied Physics

Volume 2 Issue 1 January 2022

Research Article

Challenges in Paddy Straw Procurement and its Effect on Cost of Power Generation

Manjeet Singh[1], Harpuneet Singh[2], Yadwinder Singh Brar[3], Kamalkant Sharma[4] and Himanshu Monga[5]*

[1]Research Scholar, I.K. Gujral Punjab Technical University, Kapurthala, Punjab, India

[2]Associate Professor, GNDEC, Ludhiana, I.K. Gujral Punjab Technical University, Kapurthala, Punjab, India

[3]Professor, Electrical Engineering, I.K. Gujral Punjab Technical University, Kapurthala, Punjab, India

[4]Associate Professor, Chandigarh University, Mohali, Punjab, India

[5]Professor, Electronics and Communication Engineering, Jawaharlal Nehru Government Engineering College, Sundernagar, Mandi, HP, India

***Corresponding Author:** Himanshu Monga, Professor, Electronics and Communication Engineering, Jawaharlal Nehru Government Engineering College, Sundernagar, Mandi, HP, India.

Received: September 09, 2021

Published: December 07, 2021

Abstract

The focus towards the use of biomass for Power Generation has increased intensely from the past few years because of the awareness of global warming and a bad impact on the environment due to the combustion of fossil fuels. This paper addresses the challenges for power production using paddy straw faced during the procurement and its storage. The paper opted for an exploratory study using the open-ended approach of grounded theory, including sample collection and experimenting. It has been observed that the various challenges are farmer awareness, transportation cost, storage cost, degradation due to storage and pre-feeding costs. The results have shown that there is 20.49% decrease in Calorific Value due to degradation of paddy straw at storage. The cost of generation in the month of procurement is 0.02304$/kWh and it has been increased to 0.0289$/kWh.

Keywords: Biomass Combustion; Paddy Straw; Power Generation; Cost of Generation

Introduction

The demand for Electrical Energy is increasing day by day with the development of India [1]. An increase in the demand for electricity may not be able to meet generation as per the current scenario of power production. Most of the electrical energy generated is produced from coal-based thermal power plants [2]. This also has an impact on the environment due to carbon emission and the greenhouse effect. High demand for energy has caused an increase in the price of crude oil also effects the depletion of Fossil fuels [3].

To meet the current energy demand there is a need for an hour to increase the power generation, or to present the technology, which led to an increase in the efficiency of power generation. The finite availability of fossil fuels and their impact on environment have created interest in the use of biomass as a potential energy source, within the transportation and electricity sectors [4]. In addition, to reduce the carbon emission, renewable energy generation systems can be adopted [5]. Renewable energy is available in many forms and can be used for the generation of electrical power in different

ways [6]. Biomass has an important impact on the environment and climate. As if electricity generated by using biomass instead of fossil fuels, an accountable percentage of carbon emitted each year could be avoided [7]. Biomass is a combination of lignin, hemicelluloses, cellulose, and other organics, which degrade at a different rate. Low-value biomass such as agricultural and forest residues can be converted to energy products either biological or thermochemical processes [8]. Liquid biofuels especially bioethanol provides one of the few options for the substitution of fossil transport fuels as well as power generation. Which strongly promoted in the European Union [9]. Therefore, evaluations of biomass for energy conversion is a serious matter to study the ecosystem. It also provides the system for considering the biomass value, productivity, regeneration, decomposition, and combustion effects.

The environmental subject of global concern the assessment of biomass will straight away assist for the prediction of an increase in CO_2 content in the atmosphere [10]. Biomass is one of the ways to reduce NOX and CO_2 formation. Some of the researchers have also investigated that the use of different biomass for co-firing, which results in decreasing the emission of carbon and reduce the power production cost [11]. Biomass accessibility and availability in the market is the main challenge for the utilization of biomass [12]. The potential flow of agri-waste biomass for bioenergy from agriculture fields is uncertain and needs to be assessed before policy intervention can be successfully employed [13]. There are many types of research and technological survey available, but further research and development are required in order to make renewable energy systems more cost-effective [14]. There are many biomass based thermal power plants being installed under Energy Development Agencies, that use paddy straw for power generation.

Problem formation

For the usage of renewable energy, the research needs to be conducted for the investigation of current energy systems, especially for power production from biomass. The researchers not yet analyzed the large number of unidentified factors involved in biomass procurement. The research needs to address the requirement of biomass collection at a local level might be sufficient or might require to collect from larger areas for the generation of electricity. The researcher must study procurement model for the same to develop the sustainable and efficient power generation. In addition, the cost of procurement of required biomass must be included in study. Factors of Storage of biomass and the influence of aging of stored paddy straw must be investigated. Considering the current issues, further research needs to be carried out for the improvement of power production using biomass or adapting new technologies or techniques to increase the efficiency.

Methodology

The research is divided into various steps, figure 1 below shows the identified challenges while procuring paddy straw and adopted methodology. The study of Paddy straw procurement is conducted for all the Biomass power plants, by visiting there and meeting with the farmers, contractors and logistical department of the respective Power plant thereby investigating and proposing better procurement method.

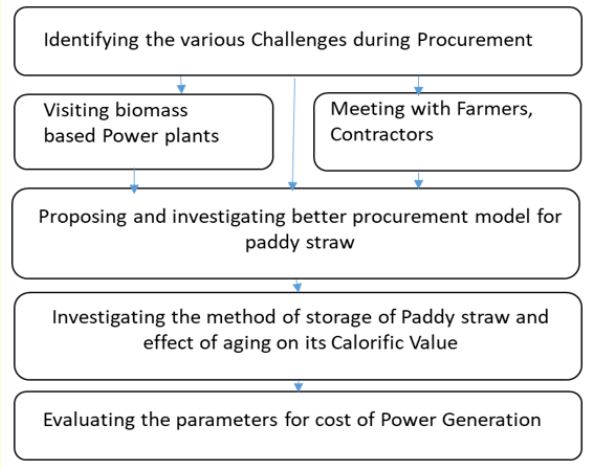

Figure 1: Methodology flow chart.

Further study has been investigated for the influence of aging on the calorific value of stored biomass and better method of storage of paddy straw. Samples of paddy straw stored were collected from all power plants and stored in the laboratory under the roof. Testing the samples of paddy straw has done every week by using Bomb Calorimeter in Non-Renewable Energy Resource Lab at Guru Nanak Dev Engineering College, Ludhiana, Punjab, India. Then parameters for the evaluation of cost of generation are discussed.

Result and Discussion

Procurement challenges and proposed procurement model

After visiting all the biomass power plants procurement methods adopted by them has been recorded. The current procurement

model for Paddy straw being adopted by most of the biomass power plant has many challenges. The challenges observed during visiting and investigating the procurement of paddy straw:

1. Awareness to the farmers and local villagers near power plant.
2. Preparation of the paddy straw for collection and transporting from fields to a storage location.
3. Facility and area of storage location.
4. Transportation cost.
5. Degradation of paddy straw.
6. Pre-feeding process and cost.

The model in figure 2 represents the better way to counter above challenges

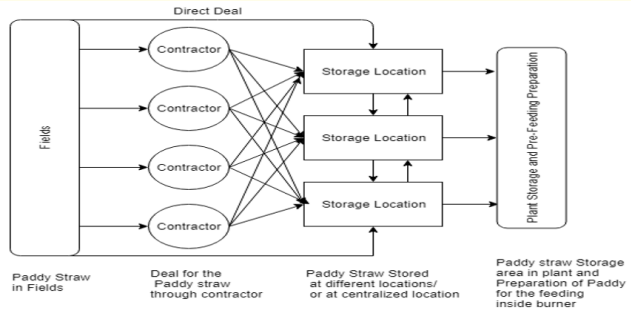

Figure 2: Paddy straw procurement model.

The model stated that the process of procurement starts when paddy yields, mostly in the month of October every year. After crop yielding the farmers are left with the agri-waste i.e. paddy straw. Most of the farmer burn this waste in the fields, which leads to the wastage of agri-waste and effects the environment because of the pollution due to burning. Farmers can sell their paddy straw to Power plant through contractors or directly to Power-plant Companies. Paddy straw is then taken from fields to different storage locations allocated by Power Plant Companies. Alternatively, in some cases storage location within the plant can be used to store the paddy straw. Therefore, paddy straw can procured in two types of locations storage location and Plant Storage location. The above model addresses all the challenges, which were observed during the procurement.

First, total requirement of the paddy straw to generate power for the whole year is must be correctly predicted. After this, it is required to make farmers and local villagers aware, which can been done by campaigning at different areas nearby time to time during the yielding of the crop. Farmers were educated about the worst effect of burning paddy straw in fields and deals of selling paddy straw have been made between farmers and power plant officials or Contractors. Local contractors had been motivated to collect more paddy straw.

Second, now after crop yielding, the challenge is to collect paddy straw and store at different locations. For this paddy straw needs to be balled. The balling process includes a baler machine that may be provided by power plant Company on a rent basis or by the contractors. The government agencies can also promotes this event by giving subsidies to baller machines. This in turn, will has increase the awareness in farmers to use of paddy for power production and avoid the burning of paddy straw in fields. After the bailing process, the paddy is transported from fields to the nearest storage location. In some cases, paddy is not being balled but it is kept in pits and stored. The balling process also includes cost for the same.

Third, is the facility at storage area: most of the storage area is open space and ground, but for the better storage ground must be prepared. For open storage location, cementing or wooden flooring is preferred to increase the accessibility. It also helps to reduce the deterioration of paddy straw in case of rain by transferring the rainwater flow away from the paddy. While if paddy is stored under the roof it will ensure less deterioration due to rain or weather conditions. Storage location includes the cost of land, which can be taken on lease or can be purchased by the power plant company. More cost of land will lead to higher fuel costs.

Forth is transportation cost, which includes the cost of labor for the loading, cost of unloading, cost of rent of vehicle used and cost of fuel used during the transportation process. Transportation is dine for paddy straw from fields to storage location and then from a storage location to the power plant, or paddy straw directly transported from fields to the power plant.

Fifth, the degradation of paddy at a storage location. Due to microbial composition in biomass material and presence of moisture in surroundings, paddy straw degrades at the storage location. This is one of the major problems in case of power production, as

the paddy straw is procured at on time of the yielding [16]. Due to this, Power Plant Company needs to procure the quantity of paddy straw keeping in mind of degradation. Due to this fact, the calorific value of paddy will reduce which results in more usage of fuel for the generation. Investigation for the same has been done in Non-Conventional Energy Research Lab at Guru Nanak Dev Engineering. College Ludhiana. Samples from fields at a different location in Punjab, India are collected and while visiting power plants samples of paddy straw collected for the investigation. All the samples kept in the laboratory under roof.

After the procurement of Paddy, it is kept in storage space and utilized it for the whole year. This leads to the degradation of stored Paddy straw due to biodegradation, environment condition like moisture, dust, etc. The study is being conducted to analyze the change in calorific value every week by testing the samples, which are being procured from different areas. The samples, which are being procured, are kept inside and calorific value is being tested for all the samples using Bomb Calorimeter.

The average calorific value has been calculated by testing all the samples referred in table 1. In addition, the obtained calorific value of the paddy straw is not found to be the same as it was procured. It tends to decrease every month, which results in the total decrease of 20.49% from the initial value after one year.

Month	Calorific Value Week 1 (kCal/kg)	Calorific Value Week 2 (kCal/kg)	Calorific Value Week 3 (kCal/kg)	Calorific Value Week 4 (kCal/kg)	Average Calorific Value of the month (kCal/kg)	Decrease from last month value	Decrease from initial value	% age decrease from initial value
November	3756.32	3635.05	3298.26	3314.45	3501.11	0.00	0.00	0.00
December	3554.91	3482.68	3434.88	3442.16	3478.63	22.50	22.48	0.64
January	3241.86	3371.37	3347.14	3388.15	3337.73	140.90	163.38	4.67
February	3309.82	3317.67	3318.87	3283.73	3307.81	29.90	193.30	5.52
March	3394.21	3301.18	3422.86	3136.65	3313.14	-5.30	187.97	5.37
April	3354.97	3292.68	3456.62	3345.64	3362.46	-49.30	138.65	3.96
May	3338.51	3421.31	3348.09	3243.37	3337.89	24.60	163.22	4.66
June	3318.08	3287.08	3174.06	3339.94	3279.69	58.20	221.42	6.32
July	2917.51	2899.36	2902.34	3222.97	2985.83	293.90	515.28	14.72
August	3142.91	3009.54	3020.04	2924.54	3024.11	-38.30	477.00	13.62
September	2975.07	2832.81	2857.00	2805.78	2867.43	156.70	633.68	18.10
October	2811.86	2782.46	2793.55	2745.41	2783.87	83.60	717.24	20.49

Table 1: Caloric value of sample tested in lab.

Paddy straw has been procured in the month of October and November every year. The process of procurement was completed at the end of November. The graph figure 3 shows that the CV is decreasing every month but in the month of March there is a rise in the CV with respect to the CV of last month, this is because the relative humidity of the environment has decreased. Which results in the increase in the calorific value of Paddy Straw. This happens the same in the month of April and August. So, for the impact on the value of CV of Paddy straw Microbial reactions and Humidity of the environment in which is being stored plays an important role. The Average caloric value was 3501.11 kCal/kg in the month of November when procurement takes place and it is reduced to 2783.87 kCal/kg, which is about 20.49% of the decrease in the CV of Paddy straw will lead to loss of power generation and increased cost of generation.

Evaluation of cost of power generation

The effect on the cost of generation due to degradation of calorific value of Paddy straw is calculated as:

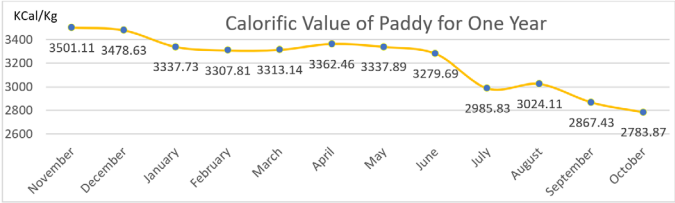

Figure 3: Calorific value (CV) of paddy straw for one year.

Assuming:

1. Total amount of paddy straw procured per year with respect to the capacity of Power Plant = *M* kg
2. Calorific Value of Paddy at the time of Procurement = *x* kCal/kg
3. Cost of Paddy straw including Balling charges, Labor Charges, Transportation charges and Interest = p$/kg
4. Fuel handling charges including storage charges, shifting charges, clipping charges 7 feeding charges = *f* $/kg

Total fuel charges = M×p+M×f=M×(p+f)$ (1)

Total energy available in kcal = CV*total Fuel Procured = x×M kCal (2)

Total energy available in kWhr. = x×M×0.0011622 [0.0011622 is the conversion factor from kCal to kWhr]

General efficiency of thermal power plant = 40%

General load factor on generator of power plant = 80%

Total energy generated = x×M×0.0011622×0.40×0.80 kWhr

Total cost of energy generated per kWhr = Total fuel charges/Total energy generated

From equation no. (1) and (2) = M×(p+f)÷x×M×0.0011622×0.40

= (p+f)÷x×0.0011622×0.40

= 2688.86595×{(p+f)÷x} $ (3)

In equation no. 3 it is observed that the cost of energy generated inversely proportional to the CV of fuel and directly proportional to the fuel charges for any value of 'M'. The value of 'p' is 20$ per Ton and 'f' is 10$ per ton for paddy straw, which is at the time of study.

The paddy straw when used for the power generation include different costs, which includes the annual storage charges per ton, Shifting of Paddy straw from storage location to Power plant, Processing of Paddy straw so that it can be fed inside the burner i.e. Chipping Charges. Process of feeding the Paddy straw inside a burner also have a cost component per ton. All this combines the total cost of paddy straw per ton which comes out to be 30$/ton. The table 2 represents the Cost of Paddy straw including Balling charges, Labor Charges, Transportation charges and Interest which is approximately 20$/ton and fuel handling charges including storage charges, shifting charges, clipping charges and feeding charges is 10$/ton.

	Fuel Handling Charges per ton (f)				
Rate per ton (p)	**Annual Storage charges**	**Shifting Charges**	**Chipping Charges**	**Feeding to burner**	**Cost per ton (p+f)**
20$/ton	1.429$/ton	1.714$/ton	5.429$/ton	1.429$/ton	30$/ton

Table 2: Cost of paddy straw and fuel handling charges in the year of 2019.

The cost of generation is increased by the decrease in calorific value of paddy straw shown in table 3 from 0.02304$ to 0.0289$/kWh.

Month	November	December	January	February
Calorific Value kCal/kg	3501.11	3478.63	3337.73	3307.81
Generation cost $/kWh	0.02304	0.023189	0.024168	0.02439

March	April	May	June	July
3313.14	3362.46	3337.89	3279.69	2985.83
0.02435	0.02399	0.02417	0.0246	0.02702

August	September	October
3024.11	2867.43	2783.87
0.02667	0.02813	0.02898

Table 3: Generation cost per $/kWhr.

The figure 4 and table 3 represents the price of power generation, which is observed to be increasing in the last four months there is a high rise because of the high decrease in the CV of Paddy straw. Similarly, the cost of generation in the month of procurement of Paddy Straw is 0.02304$/kWh and it has been increased to 0.0289$/kWh which is 25.76%.

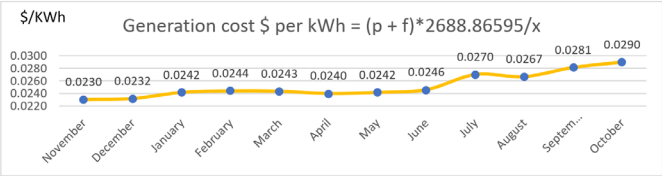

Figure 4: Cost of power generation.

The rise in the cost of generation also effects the annual return to the generation company. Our study emphasis the utilization of paddy straw for the power generation in an efficient manner by reducing the procurement losses. The study also results in the evaluation of the rise in cost of generation.

Conclusion

Most of the time farmers burns their agri-waste, which led to the increase in pollution and has a bad impact on the environment. The study insure the utilization of Paddy straw for the power generation. In this, the proposed model has been applied and various factors during the procurement of paddy has been taken care, first is awareness it must be done by educating farmers and local villagers by campaigning at different areas nearby from time to time during the yielding of the crop. Second, as paddy is cultivated only once in a year so it is a challenge for the power plants to procure and store paddy straw in a proper manner. The facility at storage area must be prepared for open storage location. Cementing or wooden flooring is preferred to increase the accessibility. It also helps to reduce the deterioration of paddy straw in case of rain by transferring the rainwater flow away from the paddy. While if paddy is stored under the roof it will ensure less deterioration due to rain or weather conditions. This will lead to low distortion of paddy straw and maintain calorific good value. The collection of the paddy from the storage location to Power plant depends on different factors such as distance from the storage location to power plant. Mostly the farthest storage location must be used firstly but in case of bad weather conditions like rain or thunderstorm, storage location that is nearer to the power plant is used. During transportation, rain or bad weather may affect the late delivery and quality of fueling paddy straw. Third, the facility of storage of Paddy Straw costs 1.429$/ton/year. Forth is the transportation cost, both bailing and transportation cost are included in the cost of paddy which is 20$/ton. The cost of fuel handling charges comes out to be Shifting Charges 1.714$/ton, Chipping 5.429$/ton, feeding to burner 1.429$/ton. The total cost of Paddy straw is 30$/ton. Fifth, the degradation of paddy straw at storage location. This results in a 20.49% decrease in Calorific Value, which in turn increases the total fuel consumption per unit of power production. This leads to an increase in the generation cost from 0.02304$/kWh to 0.0289$/kWh which is 25.76%. The study concludes that paddy must be procured keeping in mind the degradation i.e. 20.49%. The Average caloric value was 3501.11 kCal/kg in the month of November when procurement takes place and it has been reduced to 2783.87 kCal/kg that leads to loss of power generation and increased cost of generation. The above results must be kept in mind while predicting of the amount of paddy straw during procurement or some of the other agriculture waste can also be procured and utilized throughout the year to maintain the cost of generation. Due to the increase in the cost of generation, the projected economical return will be not able to meet. This will also reflects in the selling price of electricity generated from paddy straw or biomass. This study helps to calculate the actual scenario of unit cost throughout the year, which in turn helps in framing price policy, and maintain competitive power market.

Bibliography

1. VJ Gutierrez-Martinez., *et al.* "Optimal Dispatch Model for Demand Response Aggregators". *Journal of Electrical Engineering and Technology* 14.1 (2019): 85-96.
2. P Garg. "Energy scenario and vision 2020 in India". *The Journal of Sustainable Energy and Environment* 3.1 (2012): 7-17.
3. L Lillieblad., *et al.* "Boiler Operation Influence on the Emissions of Submicrometer-Sized Particles and Polycyclic Aromatic Hydrocarbons from Biomass-Fired Grate Boilers". *Energy and Fuels* 18.2 (2004): 410-417.
4. JD Martinez., *et al.* "Experimental study on biomass gasification in a double air stag downdraft reactor". *Biomass and Bioenergy* 35.8 (2011): 3465-3480.
5. NL Panwar., *et al.* "Role of renewable energy sources in environmental protection: A review". *Renewable and Sustainable Energy Reviews* 15.3 (2011):1513-1524.

6. L Tripathi Renewable., *et al.* "energy: An overview on its contribution in current energy scenario of India". *Renewable and Sustainable Energy Reviews* 60 (2016): 226-233.

7. AS Suntana., *et al.* "Bio-methanol potential in Indonesia: forest biomass as a source of bio-energy that reduces carbon emissions". *Applied Energy* 86 (2019): S215-S221.

8. AK Sharma. "Experimental investigations on a 20 kWe, solid biomass gasification system". *Biomass and Bioenergy* 35.1 (2011): 421-428.

9. R Luque., *et al.* "Biodiesel as feasible petrol fuel replacement: a multidisciplinary overview". *Energy and Environmental Science* 3.11 (2010): 1706-1721.

10. SS Saatchi and M Moghaddam. "Estimation of crown and stem water content and biomass of boreal forest using polarimetric SAR imagery". *IEEE Transactions on Geoscience and Remote Sensing* 38.2 (2000): 697-709.

11. A Demirbaş. "Biomass Co-Firing for Boilers Associated with Environmental Impacts". *Energy Sources* 27.14 (2005): 1385-1396.

12. K Havlíčková., *et al.* "Modelling of biomass prices for bio-energy market in the Czech Republic". *The Journal Simulation Modelling Practice and Theory* 19.9 (2011): 1946-1956.

13. N Sasaki., *et al.* "Woody biomass and bioenergy potentials in Southeast Asia between 1990 and 2020". *Applied Energy* 86 (2009): S140-S150.

14. N Lior. "Sustainable energy development: the present (2009) situation and possible paths to the future". *Energy* 35.10 (2010): 3976-3994.

15. T Lap., *et al.* "Pathways for a Brazilian biobased economy: towards optimal utilization of biomass". *Biofuels, Bioproducts and Biorefining* (2019).

16. DC Pedraza-Zapata., *et al.* "Promising cellulolytic fungi isolates for rice straw degradation". *Journal of Microbiology* 55.9 (2017): 711-719.

17. R Lou., *et al.* "Pyrolytic products from rice straw and enzymatic/mild acidolysis lignin (EMAL)". *Bio Resources* 5.4 (2010): 2184-2194.

18. S Garivait., *et al.* "Physical and chemical properties of Thai biomass fuels from agricultural residues". In The 2nd Joint International Conference on. Sustainable Energy and Environment (2006): 1-23.

19. L Cuiping., *et al.* "Chemical elemental characteristics of biomass fuels in China". *Biomass and Bioenergy* 27.2 (2004): 119-130.

20. B Jenkins and J Ebeling. "Thermochemical properties of biomass fuels". *California Agriculture* 39.5 (1985): 14-16.

21. TA Smythe. "A preliminary socio-economic, technical and environmental feasibility study for Waste for Life in the Western Province of Sri Lanka". University of the West (2011).

22. BM Jenkins., *et al.* "Combustion properties of biomass". *Fuel Processing Technology* 54.1-3 (1998): 17-46.

23. R Saidur., *et al.* "A review on biomass as a fuel for boilers". *Renewable and Sustainable Energy Reviews* 15.5 (2011): 2262-2289.

24. MR Islam., *et al*. "Characterization of biomass solid waste for liquid fuel production" (2001): 77-82.

25. Z Liu., *et al.* "Energy from combustion of rice straw: status and challenges to China". *Energy and Power Engineering* 3.3 (2011): 325.

26. K Phichai., *et al.* "Prediction heating values of lignocellulosics from biomass characteristics". *Journal of Chemical, Molecular, Nuclear, Materials and Metallurgical Engineering* 7.7 (2013).

27. SS Abdullah., *et al.* "Thermogravimetry study on pyrolysis of various lignocellulosic biomass for potential hydrogen production". *In Proceedings of World Academy of Science, Engineering and Technology* (2010): 129-133.