



Assessment of the Effect of Solar Powered Milk Cooling Technology on Small Holder Dairy Farmer Earnings, Siaya County, Kenya

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Abstract: The dairy industry in Kenya is dominated by small-scale farmers and is the most developed of the livestock sub-sectors. Yet, 85% of the approximately 850,000 small-scale dairy farmers have no access to electricity. The farmers lack access to milk cooling facilities and their milk is often spoiled and wasted. Solar and other renewable energy technologies can significantly enhance energy access, and thus contribute to economic and social development. The Program of Accompanying Research for Agricultural Innovation and the Green Innovation Centre developed clean energy solutions to improve milk quality along the dairy value chain in Kenya. The purpose of this study was to assess the impact of solar powered milk cooling technology (SPMCT) on earnings of small holder dairy farmers in Siaya County. The study used purposive sampling design to recruit farmers who were registered to use the SPMCT to preserve their milk in the study site. A survey involving all the 35 farmers incorporated in the SPMCT in Nyalgunga Village of Alego Usonga Sub County was employed. Data on performance of the SPMCT was obtained from the dairy farmers using a pre-designed questionnaire. Analysis was done using summary descriptive statistics using statistical package for social science (SPSS). Among the respondents 51.4 % were female and 48.6 % were male. The results of the study (paired t-test) indicate a statistically significant difference in earnings before and after introduction of SPMCT ($p \leq 0.05$) with a mean earning of KES. 5,462 before and KES. 12,253 after introduction of SPMCT. The county and national government need to invest in programmes to increase access to SPMCT to individual farmers in all the parts of the country.

Keywords: Solar Powered, Cooling Technology, Smallholder, Earnings.

INTRODUCTION

1.1 Background Information

Agriculture is the backbone of Kenya's economy and accounts for about 19 % of the gross domestic product (GDP), 75 % of Kenya's labour force is within the agriculture sector (MoALF, 2013). According to Kenya's Ministry of Agriculture, Livestock and Fisheries (MoALF) the dairy industry accounts for 14% of Kenya's agricultural gross domestic product (GDP) and 6-8 % of the overall GDP (MoALF, 2013). Milk production has been identified as a key contributor to at least three of Kenya's Big Four strategic priorities: health, food, nutrition, security, and manufacturing (Ndambi *et al.*, 2018). Kenya produces over five billion

liters of milk per year and is the leading milk producer in the East African region (Ajwang and Munyua, 2016). The milk industry is a source of livelihood to about 1.5 million small-scale farmers with 3 – 5 cows that contribute 80 % of the marketed milk (USAID KAVES, 2017; KDB, 2018). The country relies heavily on smallholder farmers in the dairy sector who play a significant role in feeding both the urban and rural population. Small scale dairy farmers face constraints related to milk production which include seasonality of production, high cost of inputs and poor dairy practices, which lead to milk contamination (KDB, 2017). In particular, product contamination with microorganisms is a major concern to the dairy industry since milk is transported at temperatures permissive for the growth of microorganisms (Gandhi, *et al.*, 2020). Milk chilling during transportation has the potential to substantially reduce spoilage by slowing bacterial growth, yet, 85% of the 850,000 small-scale dairy farmers in Kenya have no access to electricity (Foster *et al.*, 2015; Kabui *et al.*, 2015; Nyarugwe *et al.*, 2018). Inadequate or lack of access to electrification limits the deployment of technologies to enhance quality milk management. Equally there has not been an economical method available for on-farm milk chilling for the vast majority of small-scale dairy farmers (FAO, 2018). Poor upstream milk production practices cause milk spoilage and lost farm earnings along the downstream dairy value chain (FAO,

2016). Due to lack of refrigeration and low standards of hygiene, milk that reaches the cooperatives has a high bacterial count resulting in poor quality dairy products (Kurwijila, 2016). Raw milk provides physico-chemical environments,

which favour the growth of a broad spectrum of bacteria. Milk maintained at 15 ° C during transport potentially eliminates possible contamination, since most milk spoilage bacteria require higher temperatures for proliferation (Foster *et al.*, 2017).

Eighty percent of electricity in Kenya comes from renewable sources making Kenya's electricity power mix among the most sustainable in the world (Kiplagat *et al.*, 2011). Renewable energy technologies have the potential to contribute to economic and social development through enhanced energy access. Kenya has abundant renewable energy resources such as biomass, solar, wind, biofuel and geothermal (Kiprop *et al.* 2019). Among these, solar is the fastest growing renewable energy technologies with a potential to enhancing energy access and contribute to economic and social development (Muok and Makokha, 2017). Kenya has a vibrant and fast growing solar energy market among the developing countries (Muok and Makokha 2017). Introduction of solar powered milk cooling systems (SPMCS) into the milk value chain has the potential to reduce losses and wastage due to milk spoilage (Rojas *et al.*, 2018). This will create more opportunities such as better payment to dairy farmers due to increased quantity and quality.

Jaramogi Oginga Odinga University of Science and Technology in partnership with University of Hohenheim piloted the use of SPMCS for milk preservation in Siaya County. This was through a collaboration with the Program of Accompanying Research for Agricultural Innovation (PARI) supported by the German government to enhance the quality of milk from producers in remote parts of Siaya County where electricity supply is unreliable. The program installed three SPMCS and supplied some farmers with insulated milk mazzi-cans with ice chambers that cool milk at 15° C during transport to cooperatives and collection satellites. Since the installation of the SPMCS, no study has been conducted to evaluate

effectiveness of the system in improving milk quality and earnings of the smallholder farmers in the study region. This study was undertaken to evaluate efficiency of the system performance with respect to the economic impact of SPMCS on the earnings of the smallholder dairy farmer in the study region.

2.0 MATERIALS AND METHODS

2.1 Study site

This study was conducted in Siaya County, within Nyalgunga location in Alego Usonga Sub-County. According to the Government of Kenya (GOK, 2015), Siaya County has a land surface area of 2,530 km² with a water surface area of 1,005 km². It is bordered by Busia County to the North West, Vihiga and Kakamega counties to the North East, Kisumu County to the South East and Homa Bay County across the Winam Gulf to the South (Figure 1). The County lies between latitude 0° 26' South to 0° 18' North and longitude 33° 58' and 34° 33' (Government of Kenya, 2015). The County experiences a bi-modal rainfall, with long rains falling between March and June and short rains between September and December. The relief and the altitude influence its distribution and amount. Siaya County is drier in the western part towards Bondo and Rarieda sub-counties and is wetter towards the higher altitudes in the eastern part particularly Gem, Ugunja and Ugenya sub-counties. On the highlands, the rainfall ranges between 800 mm –2,000 mm while lower areas receive rainfall ranging between 800 –1,600mm. Temperatures vary with altitude rising from 21° C in the North East to about 22.50° C along the shores of Lake Victoria while in the South, it ranges from mean minimum temperature of 16.3° C and mean maximum temperature of 29.1° C. Humidity is relatively high with mean evaporation being between 1,800mm to 2,200mm per annum within the County. The relative humidity ranges between 73 per cent in the morning and 52 per cent in the afternoon. The region is categorized as a low dairy cattle density area (GOK, 2013).



Figure1: Map showing Siaya County (Google map)

2.2 Ethical Approvals

The necessary ethical approval to conduct this study was obtained from Jaramogi Oginga Odinga University of Science and Technology Ethics Review committee (JOUST-ERC). JOUST-ERC has the mandate of National Council of Science Technology and Innovation (NACOSTI) to approve proposals and protocols for research. The study was conducted between January and February 2018.

2.3 Inclusion and Exclusion criteria

2.3.1 Inclusion criteria

The study was non-restrictive to small holder dairy farmers in-cooperated into the solar powered milk cooling technology.

2.3.2 Exclusion criteria

Small holder dairy farmers not enrolled in the solar powered milk cooling technology were not included in the study.

2.4 Sampling design

The study used purposive sampling design to recruit farmers who were registered to use the SPMCT to preserve their milk in the study site. The sample size was 35 out of 400 smallholder dairy farmers in the Subcounty. This was informed by Ministry of

Agriculture, Livestock and Fisheries (MoALF) at the County government. A survey was carried out using predesigned questionnaires to obtain information on the cost-effectiveness of the technology. The demographic data of each recruit obtained included age, gender, and educational qualifications. A participant information statement explaining the purpose of the study was provided, and a written consent was obtained indicating their willingness to participate in the study. The questionnaire was completed in English, and where necessary translators were provided.

2.5 Data handling and statistical analysis

Before processing the responses, the completed questionnaires were edited for completeness and consistency. The data was then coded to enable responses to be grouped into various categories. The analysis was executed using SPSS statistics for windows version 20.0 and the information presented in form of tables, frequencies, percentages and bar graphs.

RESULTS

Respondents' characteristics

The study involved 35 small scale dairy farmers from North Alego location of Siaya County. Among the respondents (51.4 %) were female and 48.6

% were male. Majority of the respondents (31.4 %) were above 60 years of age with 22.9 % in the age bracket 36-41 years, only 2.9 % were in the age bracket 30-35 years. Most of the respondents (48.6 %) in the study area had basic education whereas only 11.4 % had tertiary education and 20 % had never been to school.

Majority of the farmers had experience in dairy farming with 34.3 % having over ten years' experience. A greater number of farmers (88.6 %) had been trained on milk hygiene though 11.4 % had no training on milk hygiene (Table 1).

Table 1. Characteristics of respondents recruited to evaluate effectiveness of the SPMCS in Nyalgunga location, Siaya County.

Demographic factor	Frequency	Percentage
Gender		
Male	17	48.6
Female	18	88.6
Age category (years)		
30-35	1	2.9
36-41	8	22.9
42-47	6	17.1
48-53	5	14.4
54-59	4	11.4
> 60	11	31.4
Education level		
Illiterate	7	20
Primary	17	48.6
Secondary	7	20.0
TTC/ certificate	2	5.7
University	2	5.7
Farming experience (years)		
0-5	14	40
6-10	9	25.7
Above 10	12	34.3
Training in milk hygiene		
Yes	31	88.6
No	4	11.4

Farmers' connection to electricity and milk cooling

A large proportion of the farmers (71.4 %) had no electricity and used kerosene, candles and solar energy for lighting. Twenty eight point six percent had electricity as source of power and were privileged to use it for lighting and cooking. Firewood and charcoal were the major source of energy for cooking used by

85.7 % and 14.3 % of the farmers respectively. About (11.4 %) of the farmers that had electricity and installed SPMCS cooled their milk immediately after milking since they had cooling facilities. Majority of the farmers (88.6 %) did not do on farm cooling and thus had to transport their milk immediately to the milk collection center that had cooling facility (Table 2).

Table 2 Farmers connection to electricity, source of energy and milk cooling

Item	Frequency	Percentage
Connected to electricity grid		
Yes	10	28.6
No	25	71.4
Energy for cooking		
Firewood	30	85.7
Charcoal	5	14.3
On farm cooling		
Yes	4	11.4
No	31	88.6

Effectiveness of SPMCS on preserving milk quality

All the respondent (100 %) strongly agreed that there had been a tremendous reduction in milk spoilage since the solar powered milk cooling system was installed at Nyalgunga. They all (100 %) strongly

agreed that the SPMCS was very efficient. Majority of the respondents (85.7 %) strongly agreed while 14.3 % agreed that milk spoilage was a major problem before SPMCS was installed in Nyalgunga. Majority (88.6 %) of the respondents had their milk rejected while 11.4 %

had never had their milk rejected at the dairy cooperative before the installation of the SPMCS. The farmers had a number of reasons for the rejection which included abnormal smell, failed alcohol test and bad

weather (heavy rains) that rendered roads impassable and resulted in delayed milk delivery. Forty percent of the respondents strongly agreed while 60 % agreed that low income was a problem before SPMCS (Table 3).

Table 3 Effectiveness of solar powered milk cooling system on preserving milk quality

Item	frequency	percentage
Reduction in milk spoilage		
Strongly agreed	35	100
Agreed	0	0
SPMCS very efficient		
Strongly agreed	35	100
Agreed	0	0
Milk spoilage major problem before SPMC		
Strongly agreed	30	85.7
Agreed	5	14.3
Low income a problem before SPMCS		
Strongly agreed	28	80
Agreed	7	20
Milk rejection before SPMCS		
Rejected	31	88.6
Not rejected	4	11.4
Reasons for rejection		
Abnormal smell	7	41.2
Failed alcohol test	2	11.8
Bad weather	8	47.0
Improved monthly returns		
Yes	7	97.1
No	1	2.9

Impact of SPMCS on dairy farmers earnings

Majority of the respondents strongly agreed that their monthly returns had greatly improved since the installation of the solar powered milk cooling system. The results of the study (paired t-test) indicate a statistically significant difference in monthly earnings before and after introduction of SPMCT ($P \leq 0.05$) with a mean earning of KES. 5,462 before and KES 12,253 after introduction of SPMCT (Table 4). A comparison of the income before and after installation of SPMCS

clearly indicates the impact of the solar cooling system on the small holder dairy farmers' earnings (Figure 2). The cooling of milk at the collection center before transportation and the transportation of milk in mazzi cans with ice compartment reduced milk rejection at the cooperative society. This improved the earnings of the small holder dairy farmers, making dairy farming a source of sustainable income and in turn reduced poverty

Table 4 Impact of SPMCS on the earnings of smallholder dairy farmers

Item	n	Mean	min	max	SD	P value
Earnings before SPMCS	35	5462	1600	12,000	2266.51	
Earnings after SPMCS	35	12,253	3160	27,000	5160.46	0.0001

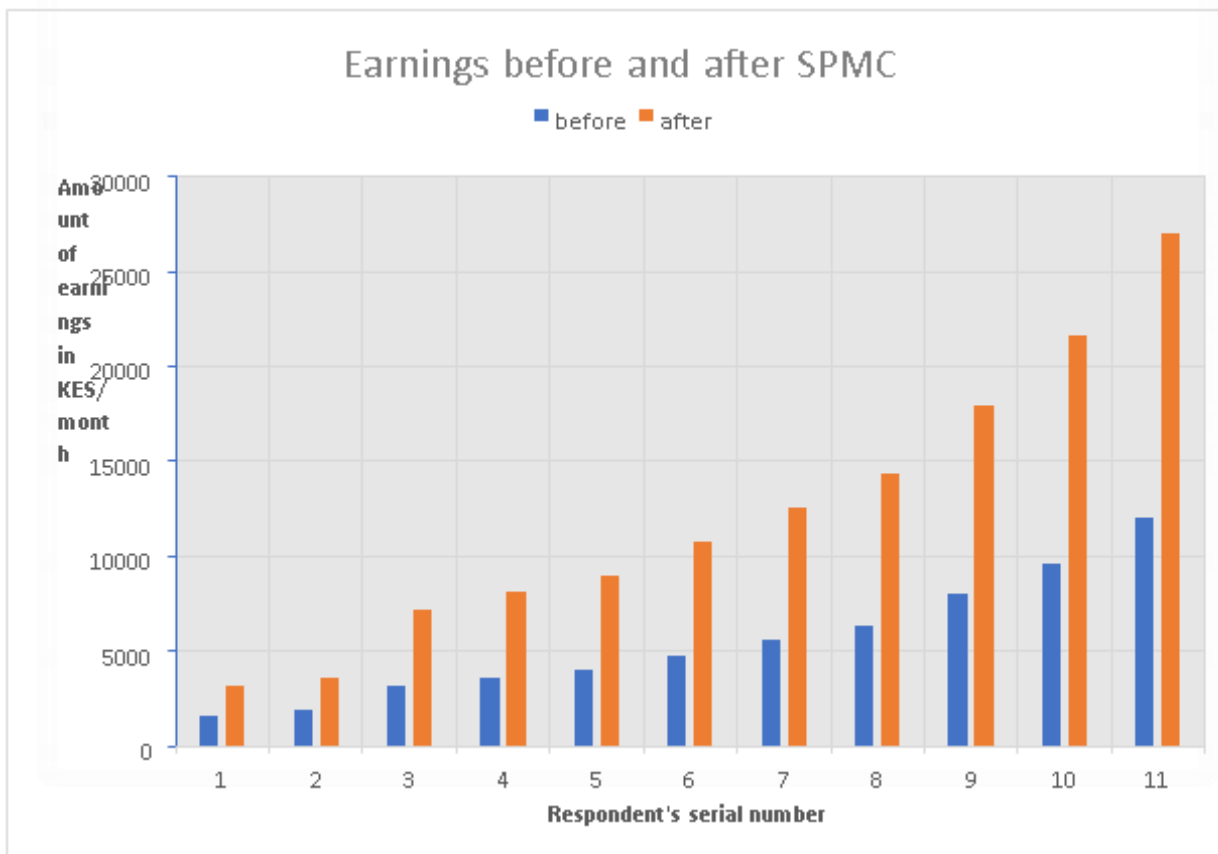


Figure 1 Bar graph on comparison of the monthly earnings of small holder dairy farmers before and after installation of SPMCS

DISCUSSION

Majority of the study participants tasked with the responsibility of animal husbandry were female (51.4 %). According to Flintan (2011) increased male out-migration in search of wage labour and other livelihood diversification opportunities resulted in more women being responsible for the home herd of cattle. Gallina (2016), reported factors that influence women’s ability to access livestock include marital status, age, and the overall production system in place. According to Njuki and Sanginga (2013), livestock are often the only asset women can own, control and sell to meet emergency and family health needs. Women in most developing countries acquire livestock through inheritance, market purchase or through collective action processes (Quisumbing *et al.*, 2015). Women are tasked with the responsibility of taking care of their family livelihoods which include cattle while men are absent and looking for wage labour in the cities (FAO, 2014).

Majority of the farmers (71.4 %) were not connected to the national electric grid and thus could not do on farm cooling of milk. International Energy Agency (IEA) records that, Kenya, Ethiopia and Rwanda have made significant steps in provision of electricity, but despite this, close to 600 million people are still without access to electricity in sub-Saharan Africa (IEA, 2019).

According to Foster *et al.*, (2015), there are over 850,000 small holder dairy farmers in Kenya, about 85 percent of whom do not have access to the national electric power grid.

Cooling milk retards bacterial growth, reducing spoilage and therefore increasing farmer income, and also ensuring the milk is safe for consumers. All the respondents (100 %) strongly agreed that there had been a tremendous reduction in milk spoilage since the SPMCS was installed at Nyalgunga. The results of this study are in line with those of Foster *et al.* (2017) where Ngorika farmers in Nakuru County using the Solar Farm Milk Coolers (SFMC) had no milk rejections whatsoever. The dairy farmers strongly agreed that the SPMCS was very efficient. According Food and Agriculture Organization, (2016) milk chilling within four hours of milking cows reduces the chances of spoilage, but that requires refrigeration units and most importantly an uninterrupted power supply.

The successful application of solar energy cooling technology in the milk value chain has the potential to improve the quality and increase the quantity of milk sold into the formal market, increasing the income of smallholder farmers and improving food safety for consumers. It can also provide opportunities for growth for businesses providing clean energy solutions.

The study results indicate mean earnings of KES. 12,253 after the SPMCS which translates to KES. 147,036 per annum for the small holder dairy farmer. This was far much more than what the farmers earned before the SPMCS was installed (KES.65, 544 per annum). The results of this study correspond with the results by Foster *et al.* (2015) who also recorded an incremental income gain of KES51,300 (US\$488) per month in high milk potential areas.

CONCLUSION

Generally, the installation of the Solar Powered Milk Cooling system had improved the livelihoods of the people of Nyalgunga, Siaya County by securing their income from sale of milk. The farmers were able to sell both the morning and evening milk, compared to previous times before the installation of SPMCS when some farmers resolved to milking only once (in the morning) to avoid wastage and loss. Milk rejection, wastage and losses had tremendously reduced and the farmers were more confident about their income generation activity. The farmers delivered quality milk thus earned premium prices and in turn poverty and unemployment levels greatly reduced.

Recommendations

In order to fully secure the income and livelihood of small scale dairy farmers the SPMCS should be extended to all the dairy farmers in the county who have no access to electricity.

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