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Diffusion of an evaporative cooler innovation among smallholder dairy farmers of Western Uganda

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In many sub-Saharan countries' dairy industries, the evening milk is either wasted or processed into low-value products because it is highly perishable and cannot be kept fresh until the next morning, when it is safe to travel (no access to electricity and night travel is unsafe). To save this milk, a "bottom of the economic pyramid" solution in a low capacity (15.5 L), evaporative cooler has been developed and its performance has been assessed while initiating its diffusion among smallholder dairy farmers of Western Uganda. The cooler successfully preserved the milk over 24 h period with acceptable quality in terms of the Resazurin test scale. Although the rate of the cooler innovation diffusion was found consistent with other diffusion studies in rural settings, interviews of participants suggested that a larger capacity cooler (50–100 L) and on-farm regeneration with biogas will accelerate the diffusion rate, affirming that at the micro-level, societal shaping of technology is indispensable to successful diffusion.

1. Introduction

1.1. The evening milk problem

Uganda is a sub-Saharan country with an estimated population of 30.7 millions, of which 85.2% live in rural areas [1] where their livelihood is derived from farming – growing crops and rearing animals. The majority fit the definition of smallholder farmers – defined by Herrero et al. [2] as those farmers with mostly less than 2 ha of land, several crops, and perhaps a cow or two, including herders (most with fewer than five large animals), and predominantly found in Africa and Asia. It is estimated that, of Uganda's total population, 68.7% are employed by the agricultural sector [1,3], which contributes 15.1% of the country's total GDP and about 90% of total exports [3–5]. The agriculture sector contribution to the country's GDP has declined over the years (e.g., from 36.3% to 15.1% between fiscal years 2004/05 and 2008/09's) [6] and is posting a growth rate of about 1.5% [7]. Contrasting this growth rate with a population growth rate of 3.2% [8,9], suggests a looming severe food insecurity. As such, the Government and the development community at large are targeting increasing food production, especially on smallholder farms, that are contributing the bulk of the country's food supply [9,10]. For example, the East African Dairy Development vision is to move smallholder farmers out of poverty by delivering farmer-focused, value-chain activities so as to stimulate dairy farm production.

The livestock sub-sector has responded favorably to development programs. For example, the total number of households rearing cattle has increased from 1.2 [11,12] to over 2.5 million between 2005 and 2009 [10,13]. Currently, the total number of cattle is estimated at 11.4 millions [14–

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16]. As a result, milk production has showed rapid growth, from 700 million liters in 2000 to over 1.9 billion liters [9,11], based on 2010 predictions (Fig. 1). There is capacity for further growth. Currently, the country exports an estimated 2% of milk production to the regional markets but this excludes significant, yet un-quantified, informal cross border trade in raw milk. It is also anticipated that if production is boosted in Uganda, it could substantially increase the country's revenue through meeting the milk deficit in its neighboring countries of Kenya, Democratic republic of Congo, Sudan, Tanzania and Rwanda [9].

Despite the great attention milk production is receiving, the postharvest losses have been estimated at about 23 million U.S dollars [9,17]. The highest losses have been identified to be at the farm level (accounting for 5.8%) and during transportation (11%) [14,18]. These losses are directly incurred by the smallholder dairy farmers. Numerous factors are behind these losses, key examples include poor road network, insufficient labor, and lack of electricity. During the rainy season, milk yields tend to increase [9,19], as feeder roads to collection centers with large (3000–5000 L) electric coolers, typically located in trading centers deteriorate; transportation of the evening milk (in the dark) becomes extremely unsafe. The problem is even aggravated by the stiff competition for market share during this period. Because milk production is high in the rainy season, the capacity of most collection center coolers is fast exceeded [9]. This forces the centers to reject all milk in excess of the cooler capacities; the most affected farmers are those who cannot transport their milk quickly enough, and these are the ones living far from the collection centers. In absence of on-farm cooling capacity, milk either spoils or is processed into low-value products like ghee. Additionally, even the morning milk that can make it into the cold chain, when not cooled immediately after harvesting, leads to poor quality [20]. Conventional on-farm cooling requires electricity supply, but the electricity grid distribution in rural areas stands at a mere 2%; woody biomass is the predominant source of energy in the rural areas [1,21]. But cooling technology relying on woody biomass has not been developed as far as the authors can tell.

A means to cool milk on smallholder farms soon after harvesting constitutes a potent change agent with respect to milk quality and quantity improvements, not only in Uganda but in many sub-Saharan countries that share the same milk production and distribution modality. Cooling milk to 4 °C within 4 h of milking meets internationally accepted milk quality standards and saving the evening milk increases the amount of milk that enters the cold chain.

1.2. The evening milk solution – adsorption evaporative cooler

The zeolite adsorption evaporative cooling technology has been adapted in the development of a cooler (560 mm high and 380 mm in diameter with a 15.5 L capacity) [22]. The cooling mechanism is based on zeolite, an alumino-silicate that adsorbs water vapor (refrigerant), a result of heat of vaporization extraction from milk when vaporized under vacuum at room temperature. At the end of the batch cooling cycle, initiated by manually lowering the pressure in the refrigerant (water) chamber via a simple switch, the zeolite is almost saturated with water, and for the cooler to cool again, the zeolite has to be dried (regenerated) by heating the whole cooler at a suitable temperature. In European markets, where this technology is used for cooling beer, centrally located large electric heaters or natural gas ovens are used for regeneration. On smallholder farm level, a biogas-fired oven (biogas regenerator) has been

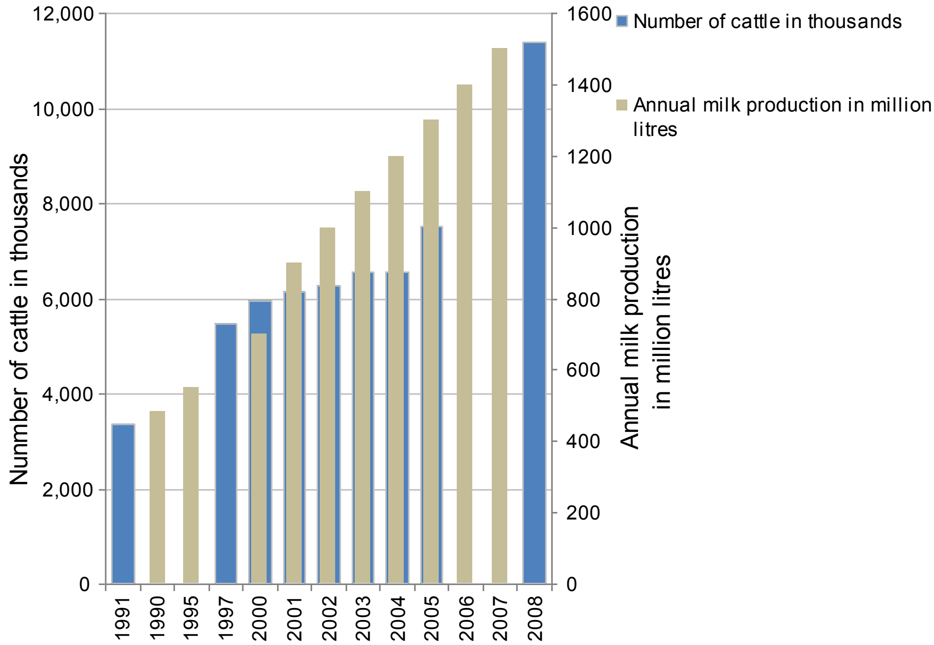

Fig. 1. The trend of the cattle herd and annual milk production in Uganda.