Adaptation of Robotic Milking of Dairy Cows in Nigeria: Constraints and Prospects

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Abstract
Milking of dairy cows was characteristically a backbreaking job which constituted great barrier to the social life of dairy farmers in the past. Having gone through different stages of development over the years, the introduction of robotic milking system (RMS) most recently brought radical changes to milk harvesting, offering great opportunities for countries with adequate potentials to expand capacity in dairy farming. This paper reports the success of robotic milking technology sequel to a visit to some dairy farms in Israel during a Mashav training. Emphasis was laid on the Lely Astronaut Milking robot (a robotic milking system commonly used on dairy farms in Europe, United States and Israel). Considering the ever increasing worldwide demand for dairy products and the amazing prospects that RMS provides for milk harvesting in dairy farming, the Nigerian dairy industry was appraised with the view to revive it from the nauseating level to which it has deteriorated. Though the importation of foreign high milk-yielding breeds of cow has failed in the past and Nigeria may not yet be ripe for RMS, vested policy interest is advocated, especially to upgrade indigenous dairy products such the *warakasi* (cheese), *nono* (fermented or soured skimmed milk), *kindirmo* (fermented whole milk) and *manshanu* (butter) through an integrated rural networking with the fulani pastoralists. These local dairy products when upgraded to international standard promises to boost income obtainable from dairy farming in Nigeria.

Key words: Robotic milking system, Dairy, Fulani pastoralists, Nigeria.

INTRODUCTION

Milking is an important part of the activities of dairy farmers (Hogeveen & Ouweltjes, 2003). Traditional milking of dairy cows was basically a manual process limited to relatively small number of cows; the need to milk a single cow two or more times per day makes the operation a tedious routine (Hyde & Engel, 2002). Attempts to develop milking machines therefore began in the 19th century (Hogeveen & Ouweltjes, 2003, Hyde & Engel, 2002) driven by the desire to improve efficiency, safeguard animal health, maintain milk quality (Hillerton, 1997), reduce the associated drudgery and create more time for the comfort and leisure of the dairy farmer. Later, the machines were complemented with milking parlours, making it possible for more number of cows to be milked within a relatively short time (Hyde & Engel, 2002). However, farmers were still tied to the rigours of strict periodic milking schedule while dairy cows were constrained to stand for long period in milking parlours. The need to do away with the boredom of this routine coupled with the challenges of initial capital, labour costs and better husbandry inspired the development of automatic milking systems (Hillerton, 1997). Generally, the use of robot for agriculture stems from the continued need to reduce human factor in agricultural operations to the barest minimum and is one of the fastest growing areas of mechanization today. The diverse nature of agricultural operations, unstructured environment, relatively low value of product and processes are some of the initial limitations of robotic agriculture (Sarig, 2006).

Some commercial dairy farms in Israel where cows are milked by robots were visited, and seeing the prospects this presents for the dairy industry globally, this paper reviews the success of the robotic milking technology. The constraints and prospects of adapting RMS in the dairy industry in Nigeria were identified and some policy interventions were suggested to maximize the potentials and benefits obtainable from dairy farming in Nigeria.

ROBOTIC MILKING METHODS

The basic elements of a robotic system are: a vision system, a manipulator, an end-effecter, a data processing and control system and the body/frame/chassis. This can be grouped into two broad parts:

i) the artificial intelligence (AI) system which consist of: a) Sensors (around/on the device): senses the environment and measures it's attribute (proximity, feel) and give useful feedback to the device b) Systems that process sensory input (signals) in the context of the device's current situation and instruct the device to perform required actions in response to the situation

ii) A wheeled platform, arm, or other mechanical component able to interact with the environment, (locomotion) and integrate all the components (Russell and Norvig, 2002).

Reinemann (1998) listed five brands of RMS in the west, they are:

i) Lely Astronaut,
ii) Prolion (Liberty) system,
iii) Full wood (Merlin),
iv) Westfalia/Surge (Leonardo) and
v) Alva Laval (Voluntary Milking System).

The most common and fast growing RMS in Israel, Europe and United states is the Lely Astronaut. Halachmi (2006[a]) reported that there are 8 Lely Astronauts on dairy farms in Israel, milking a total of

110,000 dairy cows and producing an average of 11,000 liters of milk per cow per annum.

Lely Astronaut Milking Robot

Lely Astronaut milking robot (Fig. 1) is a compact device which is made up of the following parts (Cornes 2003):

i) Milk point keyboard (MPK): This enables a number of robot functions to be operated manually. Data on milk yield and feeding can be viewed while the cow is milked when connected to Astronaut's exclusive PC; thus the cow's health history and breeding data is revealed.

ii) Milking robot control panel (MRCP): This is for the operations and settings of the machine.

iii) Feed funnel provides the cow with the ration of mixed feed.

iv) Arm: The component does the actual milking of the cow. The control system is such that the arm follows the cow's movement with high precision without hurting her and the frame of the arm is strong enough so that it is not damaged even when stamped by the cow.

v) Milking component (teat sensor, cleaning brush, teat cup). The sensor searches, scans and pinpoints each teat using laser. The brush cleans the teats and teat cups thereby stimulating the cow's udder and inducing the cow to secrete milk comfortably before milking begins. Teat cups are connected to the teats one by one and removed from the teats, again, one by one.

vi) Milk Jar: The milk taken from each quarter of the udder goes first to the milk jar where the milk is measured.

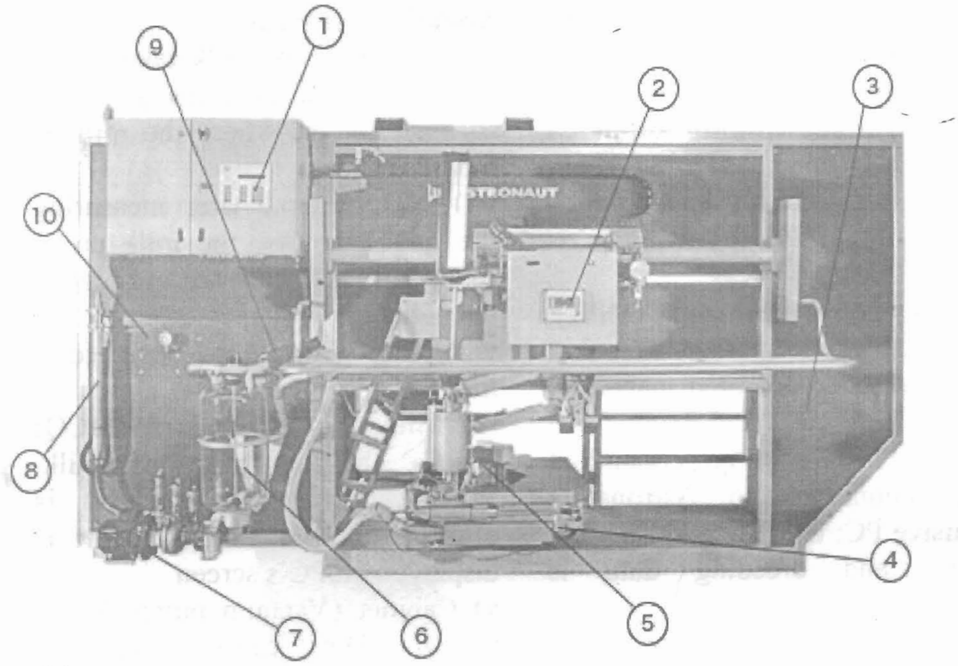
vii) Milk pump: After measuring the milk quantity, the milk pump sends the milk from the milk jar to the bulk tank.

viii) Milk filter removes dirt form the milk.

xi) Milk Quality Control (MCQ) checks the condition of milk. Whenever any abnormality is observed in the milk a report is displayed on PC's screen.

x) Cabinet (Vacuum pump, Wash tank,): The cabinet contains components which provide necessary vacuum for milking. The water heating tank prepares clean, hot water to wash the inside of the tube between the milk jar and the bulk tank.

Cows are motivated to visit the milking robot voluntarily by a concentrate feed which is programmed to be made available for the cow as soon as it enters the milking stall. As the cow enters the stall, a microchip implanted in the animal's collar is scanned for information on its milking history and health record to determine whether the cow is fit for milking or not. Based on preset standard health specifications, if the cow is found fit for milking, the robot locates the cow's udder guided by lasers; prepares the teats by washing



(1) MPK (Milking Point Keyboard) (2) MRCP (Milking Robot Control Panel) (3) Feed funnel (4) Arm (5) Teat sensor, cleaning brush, teat cup (6) Milk jar (7) Milk pump (8) Milk filter (9) MQC (Milk Quality Control) (10) Cabinet (Vacuum pump& Wash tank)

Fig. 1: Lely's Astronaut Milking Robot: A 24-hour robotic milking system

Source: http://www.cornesag.com/eng/milking/parts.html accessed on Feb 22. 2007

sterilizing and massaging it; and keys the teats into the milk cups one after the other. The system monitors milk flow such that the milk cups are removed immediately milk stops flowing (Hillerton, 1997). Immediately milking stops, the cups are removed from each teat one after the other and the milk is discarded into the milk jar for cooling and storage. Each cow has identification tags for activity measurement (ie optimal heat control) and if there is any malfunctioning during operation, an alert system sends a text message to the dairy farmer's mobile phone. (Halachmi 2006[a]) found that Lely Astronaut milking robot is almost trouble-free with 2/3 minor breakdown per year. If an animal looses too much weight during a certain period, this is registered on the attention list of the weighing unit and if the animal requires weight gain, the feed allocation for that animal increases automatically. Usually, one robot is capable of 4 milking per cow per 24 hr for a heard of about 80 cows (Halachmi, 2006[a] and Halachmi, 2006[b]). A steady stream of cows will arrive at the machines over 24 hour daily period and the robot has to adapt itself to a continuous changing set of cow parameters to milk individual cow.

Robotic Milking System's Barn Layout

Milking requires a set of skills that result in a product of lower or higher milk quality during milking, contact between the milker and the cow helps in diagnosis of abnormalities of the cow or the milk can be made. The barn layout and management of a robotic milking dairy farm must compliment the strength and weakness of the robot because most activities that are assigned to the robot bother on factors that are important to the producer, the milk buyers, regulating agencies, and ultimately the consumers (Halachmi *et al*, 2000[a] and Halachmi, 2000). The design of RMS must therefore accommodate the needs of the cow, provide comfortable space that will motivate the cow to visit the robot voluntarily and guarantee good milk quality (Halachmi, 2006[a] and Graves, 2004).

In a conventional milking system, the milker brings the cows to a waiting area from where they are forced to enter the milking parlour, whereas in RMS, cows are expected to visit a milking stall voluntarily. For most robotic processes, virtually everything is maintained at identical location, shape and size. Much had been documented on barn layout and optimization of facility allocation in relation to cow's behaviour, welfare needs and overall efficiency of a RMS (Halachmi *et al.*, 2003). Typically, when an existing herd is changed to robotic milking, it takes 3 - 4 weeks to reach a point where 85 % - 90 % of cows (most of which are the younger and more aggressive ones) use the system voluntarily (Rodenburg, 2001). Fig. 2 shows the schematic diagram of a typical RMS barn layout and Fig. 3 shows a cross-section of dairy cows at Kfar Vitkin dairy farm, Israel.

Gains and Challenges of RMS in Dairy Farming

Robotic Milking Systems have been successfully developed and are being used commercially in dairy farms across Europe, United States and Israel (Halachmi *et al.*, 2000[a]; Halachmi *et al.*, 2000[b]; Halachmi *et al.*, 2003; Reinmann, 1998 and Ipemia, 1997) and with growing acceptability in other parts of the world (Schukken *et al*, 1999). Reinemann, (1998) reported that there were over 200 commercial robotic milking systems in operation on commercial dairy farms in Netherlands, Germany, Switzerland, UK, and Scandinavian countries and in 1999 it grew to over 400 units, majority of which were in Europe (Reed, 1999; Schukken *et al*, 1999). The figure increased to 800 in Europe in 2000 (Reinmann, 1998) and presently, there are over 2,500 farms mainly in Northwestern Europe, Japan, North America, Netherlands and Israel) using RMS (Halachmi, 2006[a]). Hillerton (1997) reported that RMS have brought a radical change to milk harvesting; which hitherto was a backbreaking job and has been a great barrier to the social life of the dairy farmer.

In the conventional milking parlours, the main stress is on the lower back, wrists and forearms which lead to ailments related to repetitive motion such as Carpal Tunnel Syndrome and Tendonitis. Constant routine stooping wears out farmers' knees and hip joints. With robotic milking there are reduced injuries and accident frequencies due to operators fatigue (Cornes, 2003); thus, to an average dairy farmer, the evolution of robots for milking of dairy cows is a significant development.

Conventional milking arrangements require herding all cows through milking parlours at times scheduled by humans whereas robots allow cows to approach the stalls when pressure in their udders builds (Rodenburg, 2001). With the RMS, cows can be milked with minimal human oversight (Graves, 2004) and milk yield and milking frequency have been found to increase. This reduces stress on the udder of high yielding cows (Spahr and Maltz, 1997). In RMS, there is no strike or boredom and precision is achieved with minimum human effort while milking can go on day and night while the farmer focuses more on herd management (Stefanowska *et al.*, 1999) and can have social life. Usually cows are less frightened by machines than by people, and are free to choose their milking periods individually because they find the robotic milker more consistent and comfortable. A cow can be milked up to 6 times a day irrespective of the time whether day or night. The computerized unit of the RMS uses mobile agent to monitor individual cow's history and sends alerts to warn the farmer of unusual changes indicating illness or injury. This high-tech data collection system demands high skills on the part of the user (Halachmi, 2006[b]).

Farmers do not have to be there to milk their dairy cows early in the morning during winter; more time is dedicated to other tasks around the farm and the need for the farmer to plan daily because they find the robotic milker more consistent and comfortable. A cow can be milked up to 6 times a day irrespective of the time whether day or night. The computerized unit of

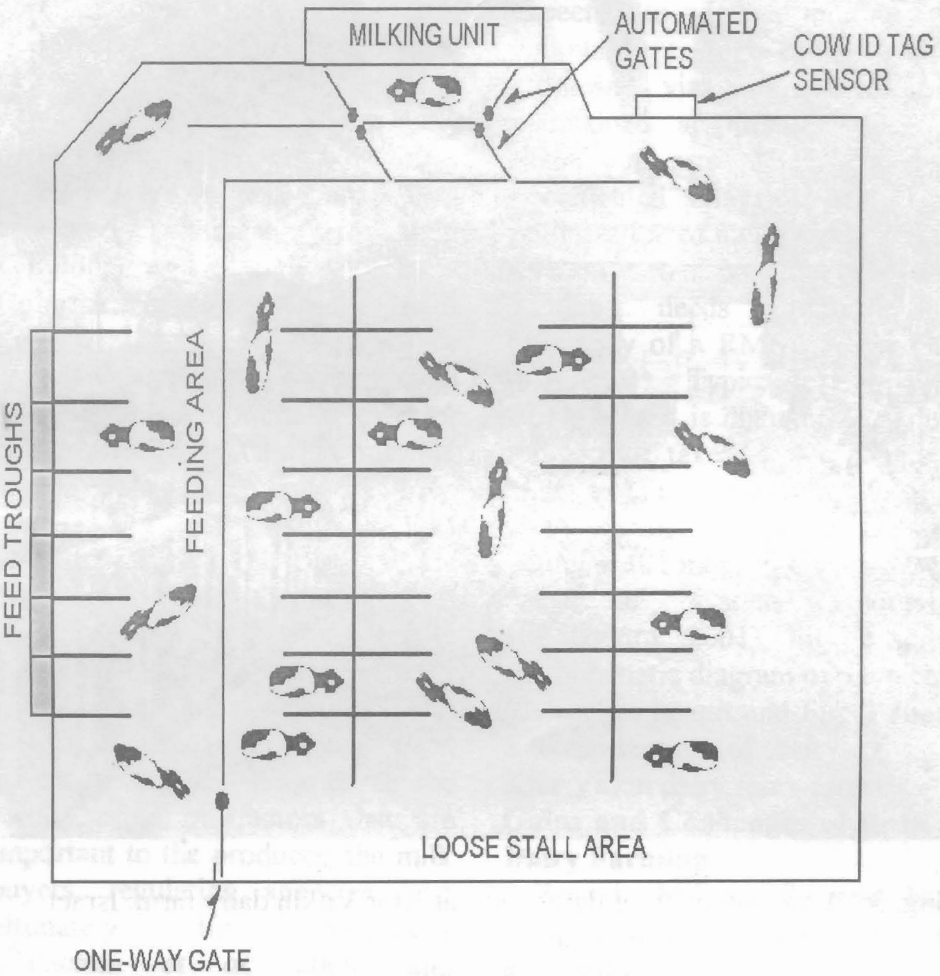


Fig. 2: A typical barn layout for RMS
Source: http://en.wikipedia.org/wiki/Automatic_milking

the RMS uses mobile agent to monitor individual cow's history and sends alerts to warn the farmer of unusual changes indicating illness or injury. This high-tech data collection system demands high skills on the part of the user (Halachmi, 2006[b]). Farmers do not have to be there to milk their dairy cows early in the morning during winter; more time is dedicated to other tasks around the farm and the need for the farmer to plan daily itinerary around strict milking times is eliminated.

For the animals, the cow determines when to be milked and can enter the unit when it is most

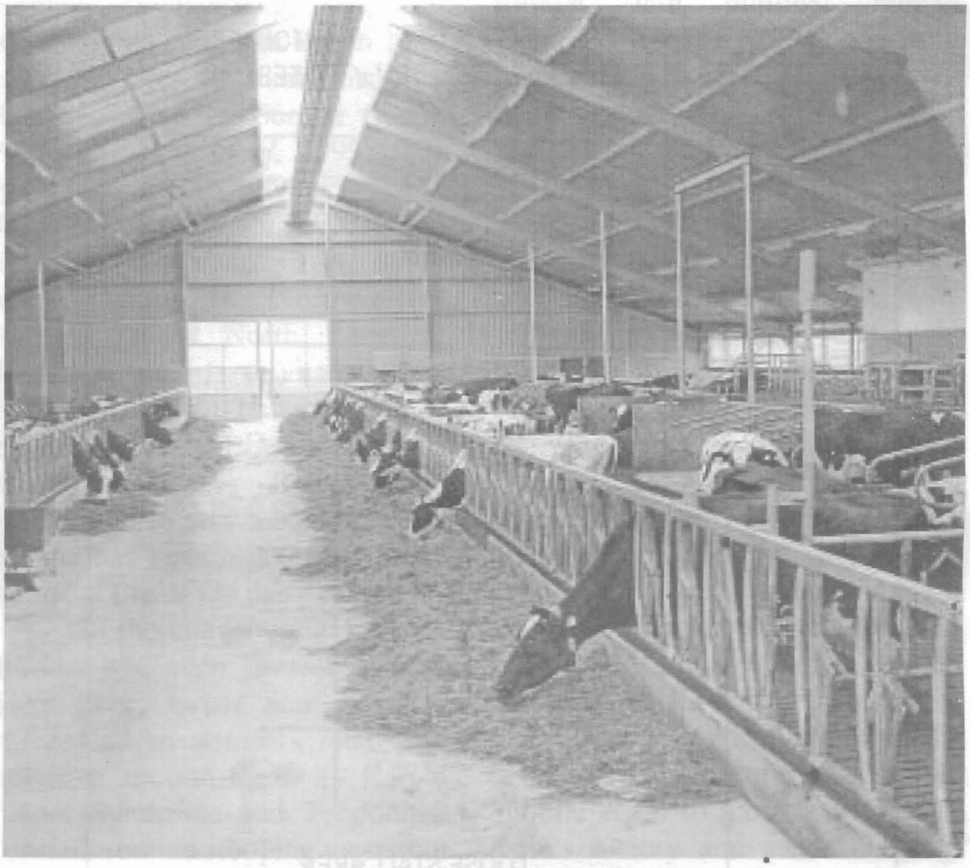


Fig. 3: A cross-section of dairy cows at Kfar Vitkin dairy farm, Israel showing the barn layout

comfortable (Spahr and Maltz, 1997). The time saved standing for long periods in collecting yards is utilized more productively. Bully cows can no longer intimidate the quiet animals and altogether, a far more restful environment for the farmer and the cow is evident coupled with better milk output. RMS works best in zero-grazing systems in which the cow is housed indoors for most of the lactation period (Reinneman, 1998). Current research in robotic milking focuses on cleaning systems of the milking equipment and the bulk tank, and on improvement of the sensors in the robot (Schukken *et al.*, 1999).

Current challenges of the RMS are milk quality, process how to utilize the new set up, leaving the cows alone to learn how to enter the milking system voluntarily; the need to train dairy farmers on information and communication technology application are some other challenges of the RMS. Increased complexity increases reliance on manufacturer maintenance services and possibly increasing operating costs. In the event of total system failure, the farmer has to rely on prompt response from the service provider. RMS removes the farmer from close contact with the animal, illness may go unnoticed for longer periods and both milk quality and cow welfare suffer. In practice, the farmers still have to inspect the herd frequently. RMS is a fully automated process which does not give room for visual inspection of the milk as with conventional milking, the milk quality is therefore managed differently. Sensors are integrated in different RMS in order to provide information on the (udder) health status and milk yield indicating the temperature, conductivity and colour of the milk (Van der Vorst *et al*, 2002). Machine milking of any kind increases somatic cell count (SCC) i.e. the quantity of white blood cells in a milk sample (Wikipedia encyclopedia, 2007). It leads to reduced udder health which results in low milk quality. Van der Vorst *et al* (2002) reported the works of previous researchers: Klungel *et al* (2000), Justesen and Rasmussen (2000), Pomies and Bony (2000) and Van der Vorst and Hogeveen (2000) who found that the milk produced on farms with RMS was significantly lower in quality than the one produced on farms with conventional milking parlours. The results of these studies showed an increase in the plate loop count (PLC) i.e. the amount of bacteria in a milk sample. High PLC in RMS has been attributed to the continuous use of milking lines (rather than twice a day in conventional systems), which reduces the time window for cleaning, and the incremental addition of milk to the bulk milk tank which may not cool efficiently at low milk levels (Schukken *et al.*, 1999). However, as experiences in robotic milking keeps building it gives room for adjustments by the dairy, the robot industry and the farmer, resulting in a better overall milk quality in the near future.

In a RMS, the tendency of dominant cows to bully their way to the robot at will thereby forcing others to milk only when there is free access is inconsistent with the perception that RMS reduces stress since animals freely choose their own milking time. The environmental concerns are that concentration of animals in zero-grazing RMS increases the accumulation of excrement that must be collected and treated by the farmer. Wikipedia encyclopedia (2007) stated that the cost of a RMS is estimated as €120,000 per milking unit (given that there is barn space for loose-stall housing) and this does not compare favorably with conventional parlours, where a much higher milking capacity may be obtained for similar or lower cost. Implicitly economy of scale cannot be used to offset the high capital investment hence the system takes longer to pay for itself than a conventional parlour. As with any technology, the economics of purchasing, maintaining and operating must be competitive with other production systems. This estimate suggests that the level of capital investment for robotic milking systems will likely be higher than for conventional milking. Generally, the long term viability of a RMS will depend on its ability to produce milk at cost which is comparable to other widely used conventional systems.

Constraints and Prospects of RMS for the Dairy Industry in Nigeria.

The dairy industry constitutes an important component of Nigerian agriculture (Olaloku 1976) from which a significant proportion of pastoralists (mainly *Fulanis*) in the sub-humid and semi-arid ecological zones of Nigeria derive their means of livelihood. Women and young girls from these pastoral households get their major income from the processing and hawking of fresh milk products such as *warakasi* (cheese), *nono* (fermented or soured skimmed milk), *kindirmo* (fermented whole milk) and *manshanu* (butter). As consumers continue to adopt western lifestyles and eating habits, the demand for high quality dairy products most of which are imported or reconstituted from imported powdered milk will continue to increase (Nzeka, 2006 and ILCA, 1976). In Nigeria, dairy products are mostly used as additives for tea, breakfast and infant cereals, ice cream, pastries, yoghurt, biscuits and other confectioneries. However, the supply of dairy products has consistently failed to meet up with demand over the last decade, thus Nigeria remains a net importer of dairy products. Nzeka (2006) estimated Nigeria's import of dairy products as 240,000 metric tons milk powder, valued about $600 million.

In the past, efforts to develop the Nigerian dairy industry focused on the importation of foreign animals, which get poorly fed and eventually become unhealthy and unproductive. This vicious cycle has run for years, whereas, the success of dairy industries in Europe, America, and Asia evolved over time, focusing on gradual improvement of indigenous methods (Ogbimi and Oyewale, 2004). Before 1960, the dairy industry in Nigeria largely depended on the colonial government farms to meet the growing demand of the cities. After the colonial era, the federal government established several dairy processing plants in Jos, Lagos, Ibadan, Kaduna, Maiduguri, Minna, Ilorin and Kano. Later, some privately owned commercial dairy farms and private milk processing plants were established. However, due to the fact that imported milk powder was cheaper, the processing plants neglected the fresh milk collection schemes and gradually the upcoming Nigerian dairy industry started collapsing (Yahuza, 2007). In some places, government owned farms were stocked with local and imported breeds of dairy cows. During this time, the Veterinary Department under the Federal Ministry of Agriculture set up collection centers and mobile collection points in northern Nigeria, where pastoral women brought fresh milk for cream separation and processing into clarified butter fat (CBF) which was exported to UK, where it was used to make expensive brands of toilet soap. Only few of these pastoralists could keep their dairy cows in one place throughout the year since there was an immediate market for all the milk they could produce (Walker, 1981). Most others only produce dairy products for subsistence purposes, their major intent is breeding cattle to accumulate stock as a form of investment (Petersen *et al.*, 2004) and later sell for slaughter as beef. The World Bank and the National Livestock Project Division had initiated a dairy co-operation program (MILCOPAL) in 2001 for procuring, transporting, processing and marketing milk collections from registered local milk producers. Other milk-collection schemes were also initiated by both the public and private sectors including Nigeria's largest dairy firm (West African Milk Company-WAMCO) for the production of butter, cheese, pasteurized fresh milk and yoghurt. Outputs from these operations, however, had either become extinct or remained insignificant. The new trend is that large multi-national firms around the world are forming alliances with the larger Nigerian dairy packaging and marketing companies, to sell their products in Nigeria (Nzeka, 2006).

CONCLUSION AND RECOMMENDATIONS

The introduction of robots into the milking of dairy cows has brought a lot of opportunities to the developed countries with adequate potentials to expand dairy capacity. In view of the need to explore nonoil forms of revenue generation and the rich potentials Nigeria has to produce dairy products, it is time more attention is given to the dairy industry. Since the importation of foreign high milker breeds of cow has failed in the past and Nigeria like most other countries in sub-Saharan Africa may not be yet ripe for RMS; an improvement and standardization of existing dairy products will be a viable option in resuscitating the dairy industry in Nigeria with the possibility of incorporating RMS in the future.

Considering the ever increasing global demand for dairy products and the amazing level that RMS has brought the dairy industry coupled with the fact that the Fulani pastoralists in Nigeria is a million light years away from robotic milking technology, low-tech, appropriate technology will be a vital option to boost milk production in Nigeria. As part of the steps to restore the viability of the dairy industry in Nigeria, an integrated network system with dairy farmers and nomadic Fulani is hereby proposed. Critical issues to consider are:

1) The Fulani pastoralists does not allow confining their cows in an enclosure for structured milking procedures as found on RMS, the proposed system therefore shall involve the use of miniature, mobile, single semi-automatic milking units which may be adapted from the existing automated methods or upgrading the vacuum pump to a solar powered unit (Hillerton, 1997) since most pastoral settlements are not on the national grid. Ownership shall be by private/public partnership. The milk collection schemes of the old should be resuscitated using designated centres and mobile units (based on agro-ecological zoning and population of dairy cows) as collection centres. Every farmer whose cow is milked should be rewarded on a pro-rated pay-as-you-milk basis. It is intended that this shall undergo a step by step development until it is possible to integrate RMS into the Nigerian dairy industry.

2) Strategic dairy farms should be established where genetically modified breeds of dairy cows like the American Milking Devon (Splan and Sponenberg, 2004) shall be developed from among local and imported stocks. These farms should be operated as demonstration centers to create awareness and sensitize pastoralists and would-be dairy farmers that better income can be obtained from dairy farming in Nigeria. There should be vested policy interest to protect and make these farms viable with the view to upgrade them and make it possible to integrate advanced technologies such as the RMS into dairy farming in the near

future. Today's consumers of dairy products are health-conscious elites who demand high quality products produced in harmony with the ecological and cultural considerations of the immediate communities. It is expected that this will produce a result different from previous instances where imported dairy cows die due to poor maintenance.

3) Milk depot should be established and designated for commercial processing of collected milk into finished products. Initial take off can be a partnership between government and private investors through the provision of incentives and credit facilities.

4) Though the importation of foreign high milk yielding breeds of cow has failed in the past and Nigeria may not yet be ripe for RMS, vested policy interest should be placed on the improvement and standardization of indigenous dairy products such as *nono, kindirmo, manshanu and warakasi etc.* These local dairy products when upgraded to international standard promises to boost income obtainable from dairy farming in Nigeria.

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