Prospects of antimicrobial food packaging in developing countries: processing and food security perspectives

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Sub-Saharan Africa (SSA) loss about 76% kilocalories (Kcal) of food produced annually before processing, which calls for urgent interventions in order to meet sustainable food security and human development in the region. The interest of international and regional institutions is aligned to increasing the agricultural productivity than reduction of massive food loss in supply chain (FSC), which leads to less sectoral transformations. This paper recommends on development of the fit-for-purpose antimicrobial food packaging materials as the factual agricultural transformation mechanism to stimulate agro-processing and sector diversification in developing countries. It endows with emphasizes on the prospects existing for the industry in SSA from food production volume, rapid urbanization, increase in middle-class society, increasingly young workforces, population growth and post-harvest loss in the region. It is well-known that the global food production is enough to feed the existing population, however due to high food loss in supply system 870 million people is undernourished. Lack of processing and packaging account for 50% of total food lost globally. Critical analysis shows that "without packaging, no processing" and establishment of food processing industries in close proximity to agricultural production settings improves food security and business value chains. Cost-effective and affordable packaging materials show to be the toolkit for nurturing and strengthening local agro-processing industry, improving food security, increasing product competitiveness and influence the production-to-consumption phenomenon.

Keywords: Agro-processing; Fit-for-purpose packaging; Food loss; Food supply chain; Post-harvest loss; Production-to-consumption

1. Introduction

Food security issues arise as special component in 2030 Agenda for Sustainable Development (SDG 2), and human development and ability standards [1]. As food security is manifested through food availability, food accessibility, food utilization and food stability in a particular community, these pillars can be dictated by engaging advanced technologies throughout food supply chain (FSC) [2]. The lack of processing and packaging materials contributes over 50% agricultural produce, which in turn increases incidence of hunger, starvation, malnourishment and diseases. The efforts played by international organizations and developing partners, especially in sub-Saharan Africa (SSA), has led to expanding cultivated land and not productivity [3,4]. The contribution of agricultural sector in food security and poverty reduction, which employs 70-80% of rural population in SSA have changed insignificantly. The cause is very clear that agricultural activities in SSA have realized poor technological transformation in the FSC, which attracts high post-harvest losses (PHL) and poor diversification on the sector. To date, no holistic measures for value addition of food products in changing market economy and lifestyles have been pursued [5]. Technology absorptions have been vulnerable to low economies of scale, socioeconomic issues and the design of many regional and international projects that attached to food productivity for self-sufficient through extension programs and nothing beyond business [6].

In fact, economic growth and development are vital in reduction of poverty and hunger in developing countries. However, scientifically the economic growth and development may have insignificant contribution in intervention of the existing hunger, without traditional-base excellent scientific initiatives and policies [7-9]. Changing paradigm in food processing is iteratively process since 1700s from food salting, sun drying, chilling, fermentation, canning, irradiation, Ohmic heating to emerging nonthermal processing technologies [10]. The current increase in population growth, population resettlement and migration, urbanization, shortage of water and climate change, all need massive contributions of science and technology. As well food security issues should deploy science and technology to give sustainable food security and cost-effective packaging materials to food producers in SSA. Thanks to current development of active antimicrobials packaging and the application of nanotechnology in food industry, which have promising future to develop packaging materials using locally cheaper and readily available materials in packaging industry [11-13].

In addition, developing sustainable packaging materials could address the contemporary trends in need of mildly processed, preserved food products and guaranteeing the safety and quality of food products [14]. From this perspective, SSA should call for policies to invest in human capital and research facilities and support the absorption of emerging technologies, technology transfer and adoptions for the betterment of the agricultural sector. Investment of science and research within the FSC with scientific consciously implementation of outcomes is important to halt food insecurity in SSA [10]. Development of agricultural sector in Asia is characterized by science and technology ideas supported with national, regional and international policies to create the connectivity of agricultural products and society needs [6,15,16].

The global food production base shows the produced food can feed 7 billion people [10,17]. However, 30-40% of food produced is lost in FSC and most of the food loss occurs in developing countries, especially in SSA [18,19]. It is estimated that 1.3 billion tons of foods, 670 million tons from developed countries and 630 million tons from developing countries [20], are lost and can feed 870 million people each year [9,21,22]. The current food loss and waste need to shift the investment strategies to perceive throughout the FSC, from agriculture for household's self-sufficient agendas to agriculture as business. Increasing the innovative technologies throughout the FSC is a necessary revitalization strategy. Situation analysis shows that investment in food processing and packaging materials would be the core modernization strategies of agricultural sector in SSA as proved in Asian countries [2,12,16,23]. Cost-effective packaging materials is an efficient and effective tool stimulating food processing, reduction of food loss and waste [15,21,23-25]. Packaging at local food producers increases the distribution succession from production-to-consumption and generate more opportunities throughout the FSC [26]. Food service creations in FSC will reduce plague-ridden foods with insects, rodents and contaminating agents like spoilage and pathogenic microorganisms of unprocessed foods [20,27-29]. It worthwhile to divert heavy amount of money channelled to support conventional projects to food processing and packaging for sustainable livelihoods of rural poor people in SSA.

This chapter is restricted to the roles of developing the packaging materials integrated with food preservatives as effective initiative for sustainable food security in developing countries. It entails in the roles of packaging technology and packaging opportunities in SSA through investing in small-scale food producers. In addition, presents the concept of antimicrobial packaging, antimicrobial agents and its relevant global industrial applications. Finally, the paper provides the potential and limitations of new technologies with respect to the scope of this chapter.

2. The roles of packaging technology in food security

Packaging technology in food industry can be defined as the technology materials for containing and protection of food products during their storage, sales, use and distribution [24]. Packaging materials are classified into primary, secondary and tertiary packaging, however, many revolving technologies for extending food shelf-life deal with primary food packaging materials [21,30]. Package comprises of packaging container, food products and headspace. Package protects food products from contact with spoilage microorganisms, chemical contaminants, moisture and oxygen intrusions and other factors such as enzymatic and biochemical reactions [31]. Food packaging, reduce the storage and handling challenges, improve transportation of agricultural products and improves the quality and safety of food products throughout the FSC [16,25]. Therefore, successful food processing industry is dependent to availability of the packaging materials [15]. This ensures that most of produced foods can be available and accessed to consumers and maintains their wellbeing, from food security point of view.

Olsson et al. [30] described packaging as the toolkit for food diversification, which cannot be ignored in FSC and as the engine of food service industry in terms of value addition, functions, customer communication, market differentiation, branding and cost aspects. It is a modernizing agent for outdoor food services including fast food outlets, restaurants, motorway service stations, bistros, cafés, motels and hotels. The food competitiveness depends on the packaging and customer profiling to the packaging materials [30].

3. Food packaging opportunities in developing countries

The global economic contributions of African countries is expected to be 25% by 2050, with the largest global workforce by 2040, increasing middle-class population comprising youth, increase in urbanization and technological advancement.

3.1 Food production and post-harvest losses

According to Manalili et al. [24] investment in packaging industry in developing countries is inevitable. The region contributes 60-80% global food production and has high agricultural growth opportunities than developed world [8]. In addition the qualitative and quantitative PHL in the region is higher accounting as lower as 10-40% and higher as 50-70% [3,19,22,32-35]. In developing countries, the loss is before processing due to lack of storage and handling facilities and transportation while in developed world food loss occurs during retailing, distribution and consumption, hence mainly PHL is determined by technological advancement positioned in FSC [9,10,12,15,20,21,36,37]. **Fig. 2** shows that 39% Kcal of food is lost during production, 37% Kcal during storage and handling, 7% Kcal in processing and packaging, 13% Kcal in distributing and marketing and 7% Kcal during consumption in SSA [29]. Empirically, low food loss during consumption implies low volume of foods enters into such segment. The data is frustrating that 76% of food produced in SSA is lost without reaching the processing and packaging stages. The question remains whether Africa needs agricultural intensifications to meet the sustainable development or not? In which extent the lost food could contribute to poverty alleviation and sustain food security of the community in SSA?

The FSC shows that empirical processing and packaging industry are vital to stabilize the food availability and price volatility in SSA by increasing the availability of foods to the higher segments of FSC from food producers [2,16,25,26,38]. Food and packaging are hotspots for pulling more food products from producers to consumers to address the production-to-consumption phenomena. However, the political structure and socio-economical state transformation should be the key changing factors for the implementation. SSA loss 20-30% of grains which can feed 48 million people per year worth more than US$4 billion annually and exceed the amount of food aid received [22,39]. In Indonesia 6% of rice substantial to feed 204 million of Indonesians are lost every year from rodents [8]. India produces 263 million tons of food and requires on 225-230 million tons per year but 40% of foods is lost worth US$ 8.3 billion [23]. Equally, the annual production data for 2005-2007 from 16 countries of East and Southern Africa for six cereal crops shows that 46.19 million tons were produced and the loss was estimated US$1594 million [34]. The annual production and value of weight loss **(in bracket**) were 27.01 million tons (920 US$ million) maize, 4.72 million tons (139 US$ million) sorghum, 1.67 million tons (60 US$ million) millet, 5.15 million tons (240 US$ million) rice, 5.25 million tons (187 US$ million) wheat and 1.71 million tons (48 US$ million) barley.

For decades no comprehensible and long-term solution has been implemented for intervention of PHL dynamics in FSC, beside various scientific recommendations [7,22,32,33]. Many recommendations and food production programs have been focusing on increasing agricultural production to meet the population growth [8,40], extension services and capacity building to farmers, hoping for more foods without empirical engagement in addressing the PHL and processing issues [3,17,29].

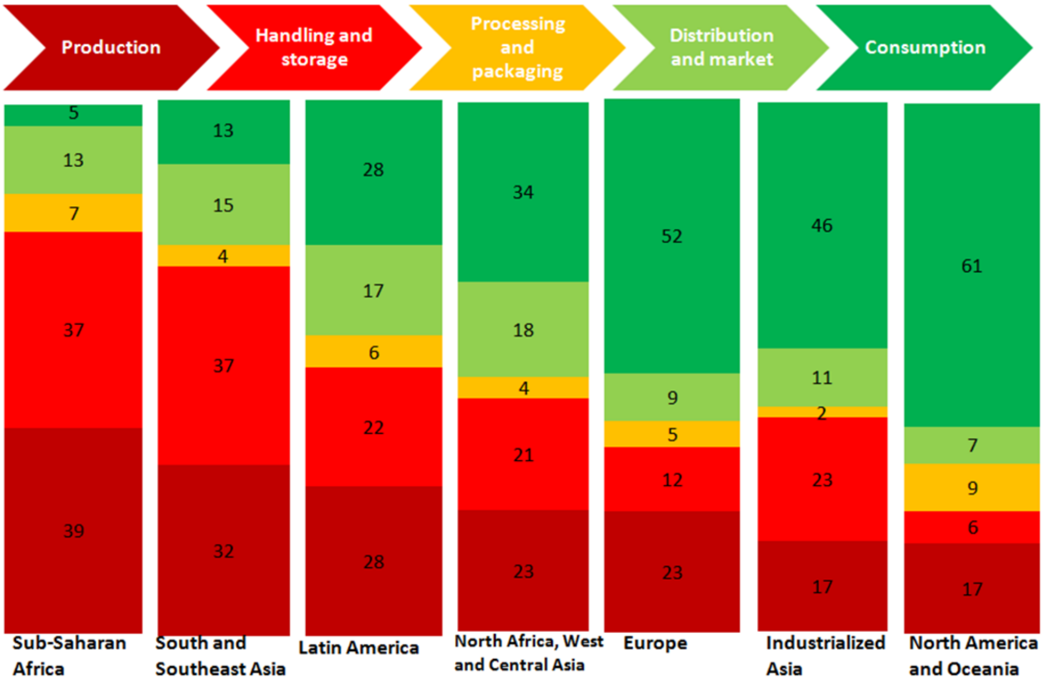

Fig. 1 Global food loss in FSC by region. Modified from [29].

3.2 Population growth and malnutrition

SSA has recorded high population rate of 949 million people and high rural-city movements of people than any region of the world [5,41]. High population and increased of skilled labor in SSA reveal new horizon of investment in agriculture and encourage this society to engage in diverse agricultural production chain. Unpredictability of agricultural activities in rural Africa cause influx of human resettlement and urbanization in Africa pointing other economic production sectors which lead to further adjustment in eating patterns and more food required in cities [16,26]. Poor agricultural diversifications and value chain lead to erratic food prices in both urban and rural areas which cause hunger, starvation, chronic diseases and malnourishment severity [5]. Between 2012 to 2014 Food and Agriculture Organization (FAO) estimated over 12.5% of world population representing 870 million people were chronically undernourished globally and 170 million are children under 5 years of age in SSA [4,10,17,23]. Considering the amount of food lost and the number of people living under severe malnourishment, we can conclude that PHL is the main cause of global malnourishment and food insecurity.

The level of malnourishment in SSA from 1990s to 2014 remains at 218-234 million people [1,36] as the reduction by about 10% from 33.3 to 23.8% compared to same in South-Eastern Asia recorded the reduction of 30.3 to 10.3% [41]. In term of population (in million) the reduction of malnourishment rate from 1990s to 2014 in Africa was 170 to 234, Southern Asia 327 to 304, South-Eastern Asia 134 to 65, Eastern Asia 261 to 167, Latin America and the Caribbean 65 to 49, Western Asia and Northern Africa 13 to 25, Caucasus and Central Asia 9 to 6, and Oceania remained 1 [10]. Stringer, [8] suggested policy-based strategies to combat food insecurity and malnourishment by encouraging international and region to support technological and research investments with increased research infrastructure and human capital. Secondly, technological scale-up of agronomical production constraints in Asia and Africa. And the last is in PHLs control which covers all prospects of food security from food availability to food stability in a particular society. PHL control measures should depict on entire and connect agriculture production to consumption through processing and packaging of agricultural yields [2].

3.3 Food processing and packaging materials

The need of effective packaging materials in development countries is derived from steady increase in food production sector, volume of food produced and increased change in daily diet pressurized high urbanization, population growth and change in daily lifestyle [5,24,26]. Olsson et al. [30] has already mentioned the importance of packaging in food service provisions in maximizing food value, diversification and food safety. In addition, cost-effective and affordable packaging material reflects food processing industry and is the means to ensure smooth supply of food from production sites to consumers during distribution and marketing [15,21,23,24]. Lack of processing and packaging account for 50% of global food loss in FSC [25,37], which falls in the scope of this chapter.

Manalili et al. [24] showed that, the volume of trade among the developed and developing countries in food packaging materials is equally shared, which in absolute term is off-shore production in vegetable, fruits and other plantation crops [1,24]. Asian countries with successful story of agricultural sector like Indonesia, the Philippines, Thailand, Malaysia and Singapore have heavily invested in food processing and flexible packaging materials to local processors since agricultural green revolution [12,16,23]. Availability of cost-effective packaging materials plays a key role in obsolete modernization of self-sufficient subsistence agricultural model to agricultural business [6,22,32]. The need for processing and packaging of food products aligned with business strategies would be of important in 21st century.

As recommended by United States, [4] governments in SSA, development partners, donors, technical agencies, civil society organizations and private sector supports are needed to create the society with high incomes, well-nourished and increased resilience [2,6]. Equally, dependency on expensive imported packaging materials remains the challenge of progressively agro-processing in SSA. **Fig. 3** shows some packaged foods in Arusha, Tanzania, depicting the levels of packaging materials at various industrial levels. In some cases, homemade and local food producers salvage the water and beverage packaging materials for packaging of juices, honeys and cooking oils among others. This group needs cost-effective fit-for-purpose packaging materials with new functionalities and efficiency.

Fig. 2 Poor and unsafe packaging materials from local agro-processors, which hinder agro-processing competitiveness as taken from Arusha, Tanzania.

Whatever so, the packaging materials used in food packaging demonstrate low competitive edge in marketplace and limit their capability for improved quality standards of the agro-products, which influence consumer discriminatory behavior. It is clear that poor packaging materials are not competitive to the current market and food consumption patterns due to quality loss from microbial deteriorations and environmental stresses. This leads to low contribution of agricultural sector in SSA poverty alleviation strategies and economic development. Therefore, nurturing and strengthening of local agro-processing and packaging industry would improve the agricultural sectors and the need for centralized food production systems with long distribution distances. New processing technologies and/or upgrading traditional processing practices which align with investments and returns are required to improve food security and malnourishment indices in SSA [7,9,24]. However, the availability of packaging materials would better reflected by building smooth supply connections from production to consumer through market networking, energy stability and affordable transport networks to support the existing and new market efficiently [3,15,17,26].

Manalili et al. [24] proposed to procure the second-hand machinery for producing the friendly packaging materials for ready-to-eat foods with some relaxations on food safety issues. This would increase the production efficiency and produce more acceptable product while staging to the next-production level and building the business chain.

4. Antimicrobial packaging and food preservation strategies

Antimicrobial packaging refers to integration of antimicrobial agents into packaging system for the purpose of preventing microbial growth on food product and extending its shelf life [13,42]. Antimicrobial packaging system aims at (i) food safety guarantee (ii) food quality continuation and (iii) shelf life extension of food products. Beneficial features of antimicrobial packages include extension of shelf life of foods, production of less expensive packages, to reduce the processing labor and use low amount of antimicrobial or produce a free-preservative package. In addition, antimicrobial packaging tends to use low amount of substance to offer maximum protection of food products because less or no inactivation of active substance occur and has localized functional effects to food surface where microorganisms tend to grow [14,43]. The activity of antimicrobials in the packaging causes the extension of the lag phase of target microorganism by contact or by slow release from packaging materials. Longer period release of antimicrobial has been the interest of many research to offer for maintained shelf life, as well as improved quality and safety of food products in FSC [42,44].

The use of antimicrobials in food packaging systems have been motivated with the safety and stability challenges of conventional food packaging. It can be broadly categorized into two main systems namely migratory and non-migratory packaging systems [45,46], however, many of industrial products in the market and active research is on the former system [42,47]. In this respect, developing antimicrobial packaging can solve many challenges of SSA food processing where local agro-processors tend to overdose the foods with preservatives. The practice, make uncompetitive food products and discriminatory consumption system at different social levels. Over-dosage of food preservative makes even more consumer vulnerable to food safety issues with foodborne outbreaks due to microbial gene resistance to preservatives, cancer, gastrointestinal tract disorders and introduction of new pathogens.

Many products show compositional inconsistencies to comply with scientific recommendations due to lack of basic knowledge and skills in food processing such as the use of chemical preservatives. The roles of regulatory authorities on providing technical and scientific recommendations on food safety issue to local entrepreneurs through extension and publicity is definitely low. With introduction of antimicrobial packaging, many packaging limitations such as availability of preservatives and packaging materials will be detached. As in many reports on antimicrobial packaging, other formants of packaging can be used out of integrated antimicrobial onto packaging materials. The use of inserts of sachets/pads in the package into the head space, polymer formulated homogenously or coated with antimicrobial compounds, and immobilization of antimicrobials to the surface of polymers would be useful for to ensure the stability of antimicrobials due to absence of cold chain facilities in many SSA [44,48].

4.1 Food antimicrobial agents

Various antimicrobial compounds are used in developing antimicrobial packaging for food preservation and extending the shelf-life. Antimicrobial compounds have the capability of inhibiting or preventing most of food deteriorating microorganisms. In practice, no broad-spectrum antimicrobial agents against all species of microorganisms like all yeasts, molds, or spoilage microorganisms. They can be used synergetically in order to achieve efficient antimicrobial properties [45]. Both synthetic or naturally extracted compounds are used and have been identified by their broad terms such as organic acids and their salts, bacteriocins, enzymes, macromolecules (chitosan), natural extracts, essential oils and fungicides have been used in synthetic polymers and edible films [48]. Others antimicrobial agents have been from nanomaterials of metals and their salts like titanium, magnesium, copper, silver, zinc, canadium, gold and carbon nanotubes (CNs) [13,31,49].

Applications of bacteriocins, enzymes and essential oils have gained interests due to their broad activity against food spoilage and pathogenic microorganisms [50-53]. Though they have processing stability limitations, their release kinetics from polymers are sustainably controlled. The instability of bacteriocins and enzymes processing conditions and interactions with the food and polymer matrices has led to limited applications in food industry. However, many efforts have been done to setup the processing condition such as pH, temperatures and speciation of packaging materials. In addition, the uses of essential oils in food packaging have been associated with strong flavor considerations since at optimal activity; tend to suppress the organoleptic threshold levels of food products. The use of metallic nanoparticles and their salts and oxides [46,54-56] as antimicrobial agents in food packaging applications is also promising due to their high stability under processing conditions. However, their applications are limited due to safety queries of the nanoparticles.

During the development of these packaging materials the regulatory concerns and stability suitability in SSA environment should be considered. However, the following general considerations should be taken in account:

(i) The effectiveness of the antimicrobial package(s) against microorganisms in designated type of foods. The best choice of packaging should be that could slow down the growth of microorganisms;

(ii) Effects of the antimicrobial additives on the final physico-mechanical properties on the package or structure. However, the effects of antimicrobial agents depend on the its amount added onto the packages as small amount added is mainly retained in the porous spaces of amorphous polymer;

(iii) Chemical nature of materials and their processing conditions on engineering processing of the package;

(iv) Ultimatum of the action, if leads to reduction of growth rate or cell death of microorganisms;

(v) The diffusion rate of antimicrobial agent(s) from package onto food matrix linking to their toxicological reaction and regulatory concerns; and

(vi) Optimal conditions for antimicrobial activities related to food composition such as pH and acidity.

4.2 Industrial landmarks of antimicrobial packaging

Antimicrobial packaging system for controlling microbial growth on some fields is widely used now in some countries [31,42,47]. In SSA, the USA based-technological company is collaborating with some Africa based companies in manufacturing biocidal mosquito nets in the region. For instance, A to Z Textile Mills Ltd in Tanzania, produces the long lasting mosquito nets to control the malarial endemic in the region. The technology is very visible and the malaria cases have been declining in some regions where the local community complies with use, as are available at subsided costs. The equivalence case can be used for developing new packaging materials incorporated with antimicrobials for food packaging to combat the PHL in developing countries. These packaging should be available at lower cost than market values or at subsidized costs to local entrepreneurs. The impact of developing local agro-processors using affordable technology to them would reduce the PHL, which in turn would improve food security.

Practically, many companies have been involved in manufacturing food related packaging materials incorporated with antimicrobials. Most products have nanomaterial-related ingredients to enhance the antimicrobial activity and performance of the packaging. Common polymers used to incorporate antimicrobials include polyolefin such as LDPE and PP, substituted olefins such as PS, polyesters like PET and polyamides (nylon). Recent literature shows that silver-based antimicrobials and migratory packaging is predominant in the industry ranges from household to consumer products [42,47]. Leading countries in manufacturing of antimicrobial food packaging are Japan and USA and other includes South Korea, China, Brazil, South Africa, and Switzerland (**Table 1**). Despite wide application of antimicrobial packaging in the developed countries, there are much stretched regulations in European countries due to safety uncertainty of antimicrobials to consumers [13,42,46].

Table 1 Summary of some industrial antimicrobial food related packaging products [31,42,45,57].

Trade Name	Antimicrobial	Manufacturing Company
Apacider	Silver zeolite	Sangi (Japan)
Zeomic	Silver zeolite	Shinanen Company (Japan)
Bactekiller	Silver zeolite	Kanebo (Japan)
Silvi Film	Silver oxide	Nimiko Co. (Japan)
Okamoto Super Wrap	Silver oxide	Okamoto Industries, Inc. (Japan)
Ionpure	Silver/glass	Ishizuka Glass Co. (Japan)
WasaOuro	Allyl isothiocyanate	Green Cross Co. (Japan)
Wasa Power	Allyl isothiocyanate	Sekisui Plastic Co. (Japan)
Ageless SE	Silver	Mitsubishi Gas Chem. (Japan)
Acticap	Ethanol	Freund Corporation (Japan)
Take Guard	Bamboo extract	Takex Co. (Japan)
Piatech	Silver oxide	Daikoku Kasei (Japan)
Microban	Triclosan	Microban Products (USA)
BlueMoonGoods™	Silver nanoparticles	BlueMoonGoods, LLC (USA)
MicroGarde	Clove	RhonePoulenc (USA)
MicroFree	Silver, copper oxide, zinc silicate	DuPont (USA)
AgION	Silver	AgION Technologies LLC (USA)
Biomaster®	Silver	Addmaster Limited (USA)
Surfacine	Silver halide	Surfacine Development Co. (USA)
Novaron	Silver zirconium phosphate	Milliken Co. (USA.)
FresherLonger	Nanosilver	Sharper Image (USA)
Baby Mug Cup (	Silver	Baby Dream Co., Ltd., (Korea)
Salad Bowl	Silver nanoparticles	Changmin Chemicals, (Korea)
Biocleanact	Antibiotics	Micro Science Tech Co.(Korea)
NS-315 Water Bottle	Silver	A-DO Global (Korea)
Cleanaid	Silver zeolite	Gyunghyang Ind. Co. (Korea)
Grape Guard	Sulfur dioxide	Quimica Osku S.A. (Chile)
Uvasy	Sulfur dioxide	Grapetek (South Africa)
Ultra-Fresh	Triclosan	Thomson Research Associates (Canada)
Sanitized, Actigard, Saniprot	Triclosan	Sanitized AG/Clariant (Switzerland)

5. Technological potentials and limitations

5.1 Potential of packaging

Many advantageous features of antimicrobial packaging for SSA have been highlighted above. The cost-effective fit-for-purpose antimicrobial packaging material in subsided values embodies two trade-off facets. The commercial and business features represent the first component of packaging materials to community. Small segment of people in rural and outskirts will engage in supply of materials and processing of agro-products which can connect the production segment to consumers out of production settings. This holds diversification aspects of agricultural sector. The second facet is that subsidized cost based on purchasing power will create more specialized agricultural segments and will address the resilience aspects of rural community, especially women and young people to control and modernize FSC from production, processing and packaging to distribution and marketing. This emphasizes the need for early technological adoptions to the large population of people hampered with low economies of scale in SSA [3,9,22].

5.2 Limitations of technological adoptions

The adoption of new technology can be received in mixed sense, that it is always dependent to political will, key stakeholder involvements, socio-economic conditions, cost involved, cultural implications and training and sensitization programs [3]. Political and key stakeholders' involvements are the key to success in any program to influence the adoption and technical backstopping of the program and market networking [9,41]. Compressive analysis shows that, the agendas on global reduction of food loss and waste are nearly triggered with strikes in food prices. Starting from 1975 to 1985 PHL reduction received high attention due to price volatility of grains in 1974 and the first World Food Conference redefined food security concept and the United Nations General Assembly adopted in its Seventh Special Session in 1975 to halt by 50% of food loss and waste by 1985 [9,20,41]. At that time, many SSA established Food Reserve Bureaus to oversee the availability of foods in their countries especially for grain [9,19,41]. After food price stabilization in 1985 many supporting nationals including Japan, UK, Canada, Denmark, Germany, Australia, USA, FAO, UNDP pulled out their support. The food crisis in 2007/08 caused riots in some 23 countries (14 in SSA) which revived again the agenda of reduction in food loss and waste [4,6,10,32]. Some efforts have been placed rigorous restructuring the existing food reserve bureaus and formation of Unclassified Food Reserve institutions to provide the early warning on the state of foods. With currents erratic droughts and El-Nino rainfall in SSA could intensify the scenarios of food insecurity redressing through mitigation of food loss [7].

Therefore, the PHLs of food might be not well addressed globally through sustainable strategies at both regional and international levels. If the issue of PHL could be addressed continuously from 1970s to 2000s, the reduction of food loss and waste could be well addressed and more foods would be available to consumers. This need joint efforts from producers, food producers, governments, regional and international institutions and private sector to reach the well-health and food secured society.

6. Conclusion: future trends in packaging

The amount of food loss within FSC globally is the current challenge to attain the sustainable food security and poverty alleviation in developing countries and especially in SSA. Also, the global population living under severe malnourishment because of low availability of food is large. However, food produced in the world is enough to sustain the current population. Government leaders, regional and international institutions should come up with tangible solutions of food loss. Conventional policies of increasing agricultural productivities have stressing the environment and ecosystem due to increased putting land under cultivation and application of chemicals. Beyond that food processing and packaging have benchmark in assisting in agricultural sector development as during the green revolution in Asian countries. Putting more efforts in processing and packaging of food products engage more people in FSC, stabilize food products, make food safer to consumers and make small farmers to think beyond self-sufficient food production scenarios. This means, without deliberate efforts in investing throughout FSC using scientific proved strategies in PHLs control, the world will not advance the food security issues and feed the hungry population.

Present understanding on the stages in which high food loss occur can help to develop more rigorous strategies and determine the efforts required to be integrated to address the problem and other related factors in the agricultural sector. In SSA where food processing and packaging marks at the lowest record, with unsafe foods, severe malnourishment, hunger, chronic diseases and food insecurity; cost-effective fit-for-purpose packaging materials are needed. Antimicrobial packaging integrated with preservatives is advantageous to address various food processing and packaging bottlenecks in SSA. The packages reduces the extra-cost of buying preservatives, can be easily used by unskilled labors and extend the shelf-life of food products for longer time compared to conventional food preservation methods. This increases margin values of food, increases food competitiveness edge, provides safer food, healthier and more nutritional food products. Therefore, antimicrobial packaging can be the revolutionization toolkit of FSC during transport, storage, processing, packaging, and distribution and finally as motivating agent for agro-processing industry in SSA.

Opportunities to establish packaging industry in SSA are many. It records, high population growth, high urbanization and high proportion of arable land for food production. With availability of packaging material agricultural production would connect more farmers that are specialized, processors, distributors and business. The production-to-consumption scenario in local agricultural production will lead to competitive food service industry for internal and international trade. Equally, it reduces the food lost unprocessed, reduces hunger and starvation and ultimate makes sustainable livelihood, health and food security. At large, the kind of packages is of paramount in this era of global food insecurity, high PHLs, global population increase, climate change, and increased competition of water for agriculture and domestic use.

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