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CHALLENGES OF ESTABLISHING THE CIRCULAR OYSTER MUSHROOM PRODUCTION MODEL IN KENYA

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Abstract: Pilze-Nagy Ltd., the largest oyster mushroom producer in Central Eastern Europe, has been applying circular model in industrial practice for years. The key is the biogas plant which secures the by-product valorisation to renewable energy and the closure of the nutrient loop by returning the digestate to the fields. To further expand the scope of this system, the company is tailoring this model in Kenya to answer the food security, climate change and demographic challenges. This follows a systematic, step-by-step method to map the local possibilities, understand the challenges and adapt our know-how through technology transfer. The circular system involves feedstock assessment and substrate development, development of the tailored oyster mushroom production circle and oyster mushroom market study. Results show that there are available different local biomass feedstocks appropriate to grow oyster mushroom even when using the traditional low tech substrate preparation method. The key market for oyster mushroom in Kenya is the urbanized and growing mid-class population of large cities, such as Nairobi. The climatic conditions of the surrounding of Nairobi (i.e. close to market) offer good conditions for mushroom growing as with minimal equipment and energy investment the near optimal environmental parameters can be set. The analyses of all steps indicate that there is potential to tailor circular oyster mushroom concept in Kenya, not just by biological, physical and climatic conditions but also considering market and economic burdens. This system further presents small-scale farmers in Kenya with diversified incomes.

Keywords: oyster mushroom, Kenya, chia, circular bioeconomy, farm income

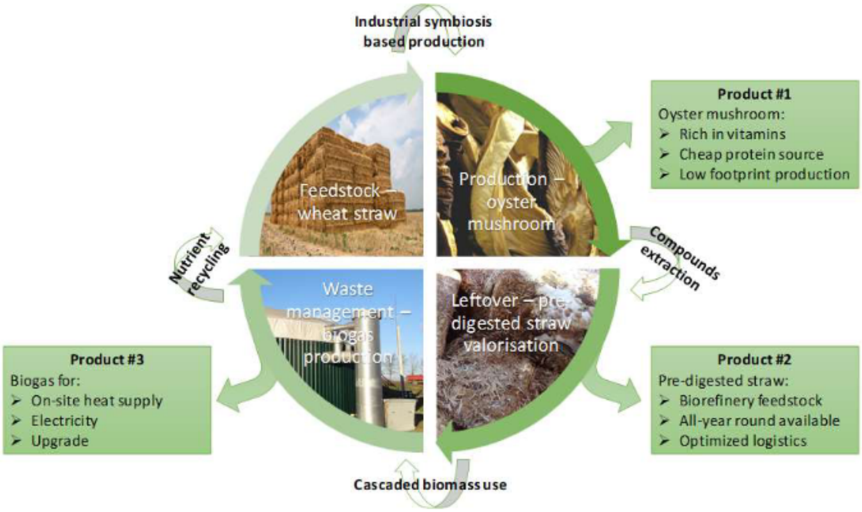
1. Introduction

Oyster mushrooms (Pleurotus spp.) are a saprotrophic group of mushrooms meaning that they feed on and obtain the necessary carbon, nutrients and energy from dead, decaying plant biomass. Under industrial production conditions this means that mostly agricultural by-products, such as wheat straw, are used as raw material for substrate production. Based on the authors' practical experiences, oyster mushroom can utilize a spectrum of agricultural (such as banana leaves and coffee pulp, by-product of coffee bean processing), forestry (such as short rotation coppice willow) and urban (such as coffee grounds) organic by-products.

Given this, the process does not require any arable land and with modern controlled environment production conditions it can become also independent from the impacts of climate change. Nevertheless, the spent mushroom substrate (SMS), the leftover after harvesting the mushroom, can create an additional waste management challenge with related environmental and economic burdens. Therefore, sustainability of oyster mushroom production is only possible if the SMS is managed properly. For example, 1 kg of harvested fresh oyster mushroom produces 5 kg of SMS (Grimm-Wösten, 2018).

As a first of a kind in the industry, with a pioneering development, Pilze-Nagy Ltd. had decided to solve this waste issue by closing the loop of the oyster mushroom production and thus creating a circular operation model. To realize this, the company built its own biogas plant in 2006 that turns the SMS and other, external biowastes from food industry to renewable energy by co-generation. The biogas unit is fully integrated into the process of oyster mushroom production, as shown on Figure 1. This valorisation, loop cycling step generates heat from the by-product to dry mushroom, provides digestate (the leftover of the anaerobic digestion) for the fields as nutrient recycling and feeds electricity to the grid. The turbulences of recent years on the energy market have shown the business rationale of the investment which now can sell energy on market basis without support.

Figure 1.: Circular oyster mushroom production by Pilze-Nagy Ltd. realized in Kecskemét, Hungary



Source: Author's own editing.

The aim of current research was to implement and expand this circular production model in Kenya with adapting each step and the applied technologies to local conditions. This paper provides an insight into this process by discussing the challenges and local conditions for each step.

2. Materials and methods

2.1. Supply chain analysis

To implement the closed loop circle and understand the relevant local conditions, the authors applied a systematic, step-by-step method to map the local possibilities, understand the challenges and adapt our know-how. First, we broke down the steps of the circle: feedstock assessment and substrate development, substrate preparation, oyster mushroom production technology scouting fitting local conditions, spent mushroom substrate valorisation, and oyster mushroom market study. This assessment is based on visits to Kenya, interactions with local stakeholders, desk-based research and local experiments and lab trials with different raw materials.

3. Results

3.1. General conditions of Kenya

Eastern-Africa, including Kenya is nowadays one of the most important and developing agricultural markets of the world. Agricultural production delivers one-third of the Kenyan GDP with an additional 27%, if counting indirect services of other sectors (FAO, 2023). This economic output is reflected also in the employment figures: 40% of the overall workforce and 70% of the rural workforce is employed in agriculture. (Trade.gov, 2023). At the same time though, the sector is dominated by small-scale farms: approximately 81% of the 8.6 million farmers owns fields with size of less than 1.2 hectares (Akuku et al., 2019).

Despite the high economic value and employment ratio, the Kenyan agriculture cannot serve fully the food demand of the country. While the improvement of food security is part of the Big Four plan of Kenya (Information.gov.ke, 2019), the sector is facing a series of environmental challenges (Kogo et al., 2020). The African small-scale farms are vulnerable to climate change and soil loss (Bryan et al., 2013).

The lack of energy infrastructure is also an obstacle for the development of the Kenyan agriculture. According to the IEA (2019) in the Subsaharan Africa, electricity is not available for 600 million people, and around 900 million people cannot use clean cooking technologies. Access to clean and inexpensive energy has an impact on agricultural development and effectiveness, too.

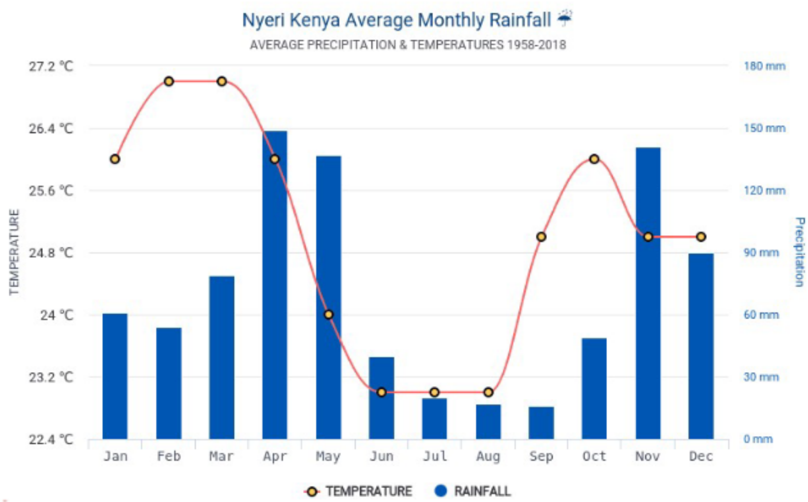
The large potential in agriculture coupled with the governmental intention to improve food security makes an enabling environment to diversify agricultural production and integrate climate-smart and new branches, such as oyster mushroom production. Nevertheless, the segmented, small-scale farmer structure may create challenges in terms of raw material sourcing by means of volume and quality. The energy challenge means an advantage for the circular approach with adding biogas as local energy source for heating, lighting and cooking.

3.2. Oyster mushroom production circle

Though oyster mushroom production takes place under controlled environment, in mushroom producing houses, the current weather conditions can influence the yields and the energy requirements. Therefore, this is the first aspect to investigate in case of Kenya. Given the location of Dedan Kimathi University of Technology (DeKUT) as the place for the pilot, the authors assessed the climatic conditions of the highlands of Kenya.

This area lays at the equator meaning constant temperature and 12 hours day-night cycles through all year. With low interdaily and yearly temperature fluctuation, the energy and technology needs are low. The climate details of Nyeri, the city hosting DeKUT, are presented on Figure 2. The temperature difference between the warmest (February and March) and coldest (June - August) months is less than 5°C. Notably, with good oyster mushroom type selection (summer strains), this temperature needs little correction. Moreover, these strains do not need sudden drops in temperature to initiate fruiting body formation. The precipitation is not evenly distributed through the year with having two wet seasons (March-May and October-December), nevertheless if water is available the necessary humidity can be secured. Due to the controlled environment the vulnerability of oyster mushroom production is much lower than of traditional, open field agriculture.

Figure 2.: Climatic conditions of Nyeri, Kenya



Source: hikersbay.com/climate/kenya/nyeri.

DeKUT has a vibrant mixed farm (coffee, horticulture and livestock) and produces a substantial amount of agricultural by-products available on-site for the demonstration of the circle. The locally available banana leaves and chia stalks are used as raw materials and complemented with other organic by-product seasonally available (including coffee pulp from the DeKUT coffee bean processing facility). Nevertheless, the authors have also assessed the applicability of Nappier grass (Cenchrus purpureus or Pennisetum purpureum), maize stover, wheat and rice straw, as generally available, low value agricultural by-products in oyster mushroom growing. Preliminary results suggest that mixing those feedstocks can make a good substrate for oyster mushroom growing.

After drying and chopping the raw materials undergo traditional substrate preparation method by using open fire for heating water in a clean oil barrel for soaking the raw material placed in a net. Prepared substrate is spawned and filled in buckets with holes on the side to be placed in mushroom growing houses with humidity control though evaporative walls and air exchange. To expand the circle, the SMS is trialled for feeding pigs with mixing with commercial pig feed. Measured parameters include body weight, mid girth expansion and palatability of the feed to the animal. Animal health is also monitored in case of any adverse reaction.

3.4. Oyster mushroom market in Kenya

In general, mushroom is considered as special delicacy in Africa, and obtained mainly from collection from certain parts of the country. Production mainly happens in small-scale serving local needs through farmers' markets. However, the market is growing, and the demand is usually higher than the actual production volume: annual 500 tonnes of mushroom production versus 1200 tonnes of demand (Xinhua, 2019). Importance of mushroom production is thus underpinned both from supply and demand sides of the market.

The reason for this is the growing urban mid-class that is demanding western lifestyle and diet with conscious consumption choices. Population of Kenya has surpassed the 50 million persons, while it was only 9.5 million in 1965 (United Nations, 2022). Traditional, small-scale farming cannot meet it not only by volume, but probably neither by constant quantity and quality demanded by urban supermarkets and restaurants. Oyster mushroom farming may mean a career opportunity for the rural population and universities, such as DeKUT can play a large role in quality education and knowledge transfer.

Oyster mushroom and in general, mushrooms can play a role also in shaping the healthy nutrition and diet. The beneficial parameters of oyster mushroom - protein, fibre and vitamin content (Rathore et al., 2017) - can contribute to a healthier lifestyle in Kenya. The current research realized this, and thus include a food development process focusing on how oyster mushroom and chia can complement the traditional, cereal (maize, millet, sorghum) based meals.

4. Discussion

Current research aims to adopt a circular oyster mushroom production model to the conditions of Kenya. After reviewing the general socio-economic environment, the authors agree that with proper tailoring the proposed model can deliver solutions to the challenges (climate change, soil loss, land use change, water management) of Kenyan agriculture while contributing to food security.

While in Europe, the main motivation for circularity is the optimization of operational costs (mainly waste management and energy), in Kenya the circularity means an option for production diversification, food security and energy access due to biogas utilization. In a broader context, it can contribute to rural development by connecting sectors of agriculture to use synergies and empower rural population. Digestate can manage soil loss, while biogas utilization replaces fire wood, thus tackle forest losses.

Despite that Kenyan small-scale farmers are sometimes conservative and produce only a narrow spectrum of goods, the Kenyan market and agricultural landscape have been changing quickly. Farmers are looking for new options and opportunities and eager to learn, at the same time urban supermarkets and restaurants wish constant and predictable supply. With knowledge transfer from abroad and the role of universities in education and showcases, this research aims to utilize its potential to develop and promote a circular model for oyster mushroom farming tailored to Kenya.

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