



Solar Foods in Sudan

Hala Ali
Ujjalpreet Kaur Dhatt

Solar Foods, located in Sudan, was established in 2017 to reduce postharvest losses, support local farmers, and empower women by providing jobs through a vision of sustainable food processing with solar drying. After severe disruptions from the COVID-19 pandemic, Solar Foods launched a promising new product line of seasonings and falafel ready mix under the brand name Doqa to make up for lost revenue. The value proposition of nutrition, authenticity, convenience, and strong social media engagement helped make the Doqa line a successful example of what can be achieved under challenging conditions. During this time, the company also optimized its solar drying technique for its high-value dried molokhia and okra powder (both significant to food security in rural Sudan), garlic and onion powders, and dried meat, which improved production efficiency and product quality (including nutrient retention).

Food Science in Action:

- ✓ Product Development
- ✓ Sensory Science
- ✓ Food Processing
- ✓ Food Safety
- ✓ Nutrition
- ✓ Ingredient Science
- ✓ Food Engineering

Introduction

Sudan-located Solar Foods is a company that uses a unique combination of food science, sustainable food processing, and solar drying techniques to create its products. By relying on industrialized solar drying methods, the company can significantly extend the shelf life of its food while using clean energy. In addition to its commitment to sustainability, Solar Foods also strives to empower women in vulnerable local communities by mainly hiring females with no formal education (Figure 1). The company's core value is supporting sustainability by reducing its carbon footprint using solar energy. They buy raw materials from small farmers, dry them, and sell them to consumers. Solar Foods also partners with NGOs to provide small solar dryers to local farmers to help them reduce postharvest losses. Smallholder farmers in Sudan lose up to 33% of the food they produce because of inadequate storage systems, which impact farmer's income, exacerbate food insecurity, and negatively impact the environment, resources, and energy. The company aims to provide cost-effective drying solutions to improve the agriculture goods supply chain over time.

Business Challenges

Solar Foods has been established in an environment with many challenges but also possesses unique strengths. A significant challenge is that the country needs more infrastructure in many farming regions. Small farmers struggle to transfer their harvest during the monsoon and flood seasons. This has a direct impact on the costs and availability of agricultural



Figure 1. Solar Foods staff members, who are mostly females without formal education. Photo courtesy of Solar Foods

goods and led to a seasonal production at Solar Foods to maintain price stability and overcome logistics issues. On the other hand, other factors, such as the fragile financial system, fluctuation in the local currency, and lack of supportive policies, created a high-risk environment to run a small business.

A key strength of Solar Food is its strong technical experience in solar energy utilization, which gives the company an advantage over its competitors. This technical knowledge allows the company to have flexibility in the design and capacity of the solar dryers used in the processing facility. The company produces high-quality dried meat, dried vegetables, and herbs using recyclable packaging to emphasize the company's core value. Another advantage is that the company uses creative marketing strategies to stand out among competitors, such as social media platforms and participating in international business events, which results in recognition for the Solar Foods brand. In 2018 the company received global recognition from MIT Enterprise Forum pan-Arab, a non-profit organization and an avid promoter of entrepreneurship and innovation across the Arab region. In the same year, Solar Foods also received Top 50 Startups in the World - Washington DC Challenge Cup completion. Also, it was selected by the United Nations Industrial Development Organization (UNIDO) to represent African startups in the World Export Development Forum 2019.

Solar Foods had low productivity in 2020 and 2021 due to disruption in the operations and supply chain issues during the pandemic, difficulties securing raw materials from the farmers, and working with fewer staff. As a response, the company had to find innovative methodologies to regain its position in the market and overcome the drop in sales by creating new B2B (business-to-business) opportunities with food manufacturers in addition to the stable consumer products that the company was selling in the retail stores. Developing ready mixes and seasonings from dried vegetables and herbs would allow the company to target new segments and expand its portfolio to create more profit.

The company hired product development staff to create a new brand, Doqa. The brand includes seasonings used in meat marination, salads, and soups, as well as ready mixes that reflect the



Figure 2. Solar Foods Products Presented in the 5th Global Food Innovation Summit (Milano 2019). Photo courtesy of Solar Foods

authentic Sudanese taste and are targeted for home cooking and food businesses.

Response

Expanding New Product Development Capacity

Product development of the new Doqa line was executed during a challenging time. The concept development started in April 2021, and launch was in March 2023. In 2021, Solar Foods, among other small businesses, hoped to receive funds as part of a financial reforms program to support the new civilian government transition in Sudan. The company was planning to invest in buying new equipment to upgrade the production line, hire more staff, and build two new large greenhouse solar dryers with higher production capacity to increase productivity. The financial reforms were canceled due to government change; therefore, the company executed the project with a limited budget. Eighty-one percent of the budget was allocated for lab equipment (Figure 3).

The goal was to use this equipment for product development and quality control tests and reduce external lab analysis costs. Some production equipment was fabricated in-house, such as a manual powder mixer. The rest of the budget was allocated for ingredients sourcing from different parts of Sudan, chemical analysis, microbiological analysis, nutritional analysis, sensory evaluation,

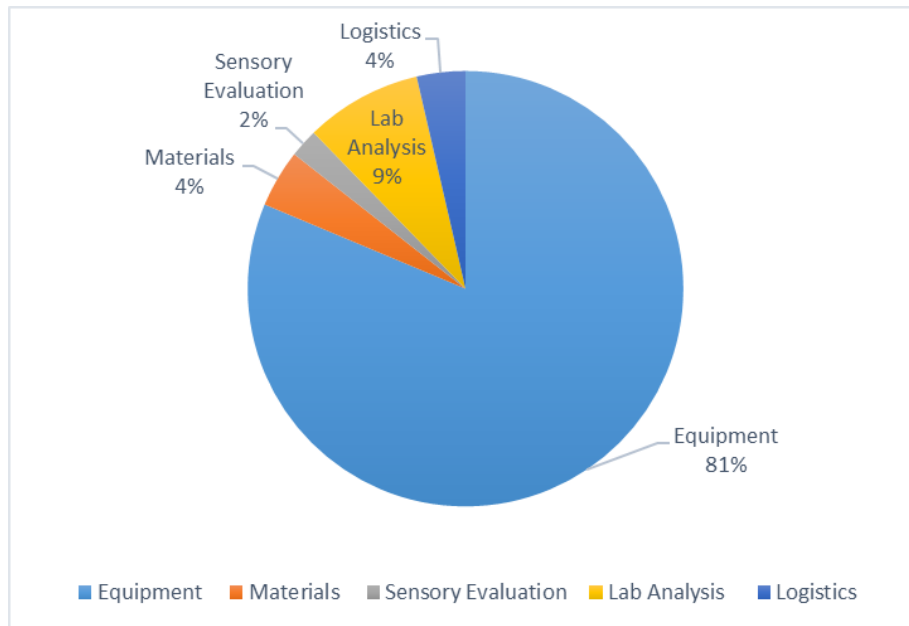


Figure 3. Breakdown of the Doga project budget. Courtesy of Solar Foods

and logistics. The product development consultant was provided with basic expenses, while the company agreed to give a percentage of sales for a specified period after launching. The total project cost amounted to approximately \$6,884 in March 2023.

Creating the new Doga product line of seasonings and falafel ready mix relied on the food science disciplines of product development and sensory science. Doga emphasizes the Sudanese taste and offers chicken seasoning, meat seasoning, salad seasoning, fava beans seasoning, and falafel ready mix. Ingredients such as chickpeas, onions, garlic, cumin, coriander seeds, chili, parsley, and dill were supplied from specific regions in Sudan that are known to provide the best quality and dried under controlled conditions to maintain their nutrition value and sensory profile. To establish the right profile matching, profiling tests were heavily used to match an authentic homemade Sudanese taste profile. That involved collecting a benchmark for each category from a specific region in Sudan to exactly match the authentic taste. Ingredients are sourced after careful screening from particular farming regions, including Alsalam, Shandi, Aljazeera, Kadugli, Tokar, and Zalingei regions. The unique sensory characteristics of the selected ingredients could be linked to the environmental factors and cultivation method, as reported.¹ This helped in creating clean-label

products free of artificial flavors, colors, or taste enhancers such as MSG.

Supporting Food Security and More

Solar Foods applied a multidisciplinary approach encompassing principles of heat transfer, mass transfer, food engineering, ingredient science, food safety, nutrition, food analysis, and sensory evaluation across various phases of the project. One pivotal phase centered on optimizing the production of high-value stable products—namely, dried meat, dried molokhia, onion powder, garlic powder, and okra powder. These products, highly sought after throughout Sudan and across diverse demographic groups, represent staples in local cuisine with molokhia and okra providing unique nutritional and health benefits.

Solar Foods' dried molokhia, boasting 23% protein and 9% fiber, stands out as a nutritionally dense offering integral to Sudanese culinary traditions. Derived from the leaves of the *Corchorus olitorius* plant, known colloquially as Jews Mallow or Jute leaves, this superfood surpasses spinach, kale, and broccoli in beta-carotene and calcium content.² Rich in vitamins C, E, and K, as well as selenium and iron, molokhia leaves are replete with triterpenes, sterols, fatty acids, phenolics, ionones, oxidase, chlorogenic acid, glycosides, saponins, tannins, and flavones.

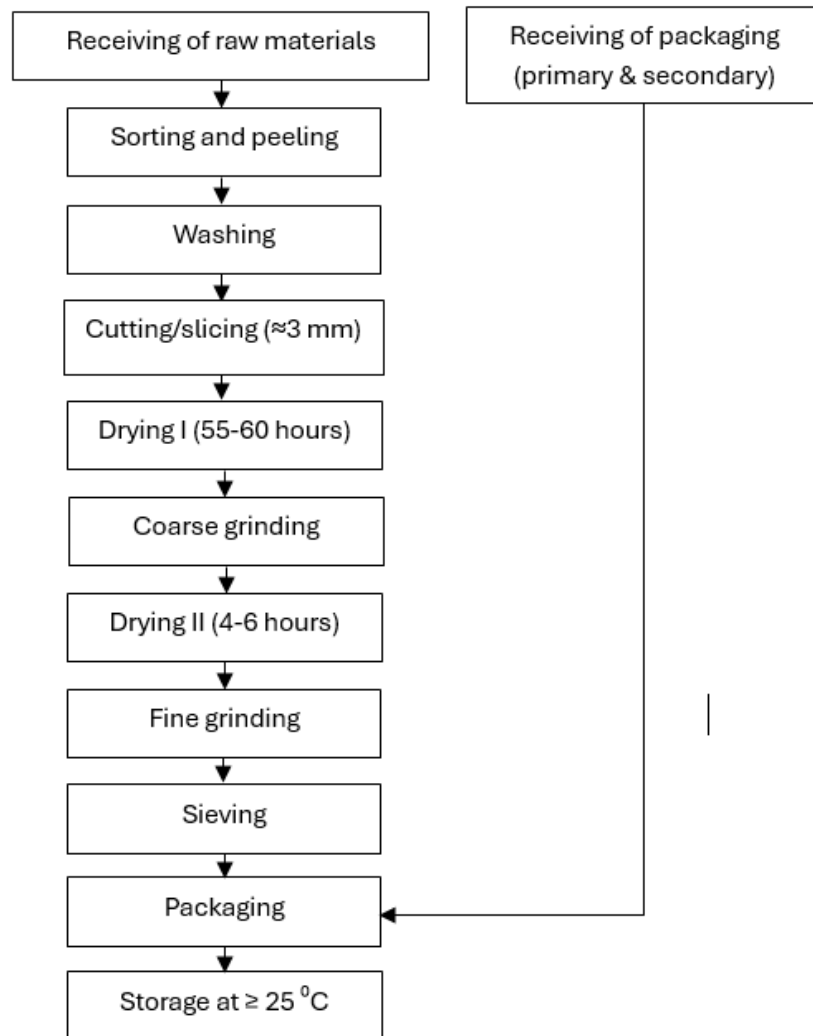


Figure 4. Optimization of the onion drying process by drying and grinding in two stages. Photo courtesy of Solar Foods

Additionally, they boast carbohydrates, proteins, fats, fibers, ashes, acidic polysaccharides, lignin, and other mucilaginous polysaccharides, constituting a comprehensive nutritional profile that also includes vitamin A (as beta-carotene), vitamins B1 and B2, folic acid, and essential minerals like calcium.³ The leaves are known to have various anti-diabetic as well as antioxidant benefits and exhibit immunostimulating, anti-tumor, and antimicrobial properties.⁴

Okra powder, with 17% protein and 19% fiber, emerges as another nutritionally dense product rich in vitamin C, carotene, iron, magnesium, manganese, zinc, calcium, copper, and phosphorus.⁵ These minerals are crucial for bone health, kidney function, nerve function, and sugar and iron utilization. The incorporation of okra into diets offers a promising alternative source of essential minerals, with reports suggesting its efficacy in supplementation and fortification to

enhance the nutrient composition and functional properties of foods.⁶

In Sudanese cuisine, both molokhia and okra are staple ingredients, often served as main dishes alongside flatbread made from whole wheat flour (Gorassa) or fermented sorghum flour (Assida or Kisra). Their role in ensuring food security, particularly in rural areas and developing countries, cannot be overstated, especially considering the convenience they offer when dried, thereby reducing preparation time, particularly for working women. Other advantages include high nutritional value per unit weight, a unique sensory profile, extended shelf life of up to 24 months under ambient storage conditions, and low energy consumption due to reduced cooking times.

Drying Optimization

The molokhia, okra, and other raw materials were dried utilizing Solar Foods dryers, designed in-house by the company, which are mainly greenhouse type (1 ton capacity per batch). These were optimized to increase productivity and improve product quality. More temperature and humidity control measures were applied inside the dryers to minimize the negative impact on heat-sensitive vitamins and enhance the aroma sensory profile. Also, the Quality Control program was updated, and more control was applied to the critical points to ensure the finished product quality standards. An example of optimization was the process of improving dried onion powder quality from caking defects toward the end of shelf-life (Figure 4). This was achieved primarily through alterations in the drying process into two steps. Initially, the onions were sliced and dried for about 55-60 hours. Then they were coarsely ground and dried for the second time for 4-6 hours at 50-55°C in the afternoon during peak temperature range before grinding into fine powder. Reducing the particle sizes and increasing surface area resulted in enhanced drying efficiency and dropped the moisture content from 13% to 6% in the final product. This improvement effectively addressed caking defects without the addition of anticaking agents. Drying

onions under low temperatures is known to enhance fatty acids and total phenolic compounds preservation and improve color and flavor characteristics.⁷

Other Food Science Efforts to Access New Markets

Solar Foods has expanded its B2B opportunities by collaborating with major food manufacturing companies in Sudan. Several meetings were held to understand the requirements and respond to their technical specifications, thus streamlining their production processes. To access new markets, upgrades and improvements in the food safety system at the company were necessary, for example, to achieve recognized certifications such as Hazard Analysis Critical Control Point (HACCP). Therefore, the staff was trained to upgrade their knowledge of food safety and good manufacturing practice (Figure 5). Quality assurance systems were updated, which included creating monitoring and validation documents, flow diagrams, standard operating procedures (SOPs), and finished product specifications.

Results

The strategic outcomes included the establishment of the new brand Doqa, the advancement of 8 additional products in development, and the rollout of 5 products by March 2023. The falafel ready mix emerged as the standout success within the Doqa line. Recognized for its cost-effectiveness, this product garnered popularity across diverse demographics, notably appealing to students, professionals, and low-income populations. Its readiness for the B2B model particularly resonated with small eateries and street vendors, offering a streamlined preparation process requiring only water for rehydration and subsequent deep frying, saving substantial time and energy during distribution and storage. Falafel also provides many nutritional benefits since it is made from ground chickpeas or fava beans, which are rich in protein, dietary fibers, and minerals, including calcium, iron, magnesium, phosphorus, and potassium.⁸ The company's online engagement witnessed remarkable growth, reaching a noteworthy one



Figure 5. Production Supervisor Zahra was presenting a case study for hazard analysis for meat drying during food safety training. Photo courtesy of Solar Foods

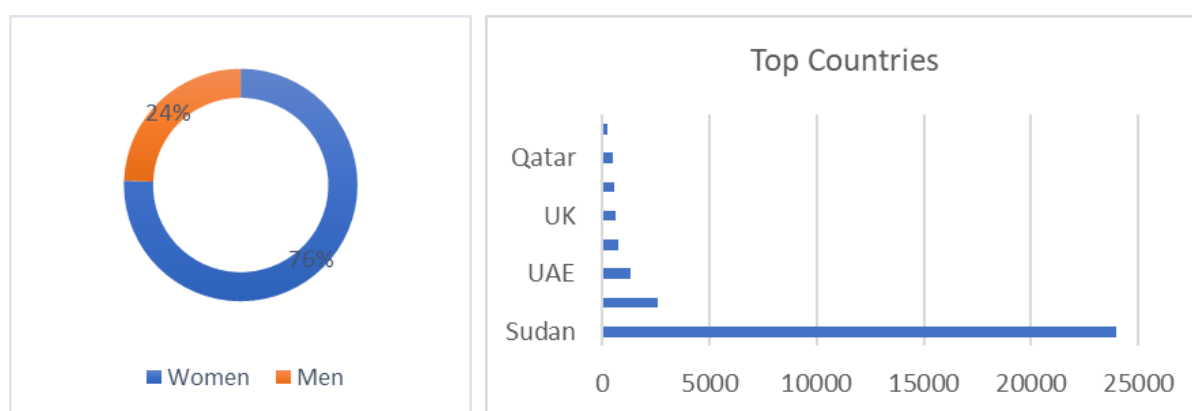


Figure 6. The gender distribution and geographical reach of Solar Foods' audience. The pie chart shows that 76% of their audience are women, while 24% are men. The bar graph highlights the top countries engaging with Solar Foods, with Sudan having the highest engagement, followed by Qatar, the UK, and the UAE. Courtesy of Solar Foods Sudan Facebook Page (<https://www.facebook.com/Solarfoodssd>)

million followers post-Doqa launch. This engagement spanned various regions, including Sudan, UAE, UK, and Qatar (Figure 6). The interest outside Sudan shows new market opportunities where Solar Food can target in the future. Utilizing short cooking videos featuring traditional Sudanese recipes presented in an accessible manner, Solar Foods aimed to inspire younger generations to explore these culinary traditions while underscoring the nutritional advantages of their products. Statistical analysis of the viewers revealed a gender distribution of 24% male to 76% female, with male respondents expressing positive sentiments about the taste and convenience of the ready mixes and dried ingredients in their home culinary endeavors.

excellence, culinary authenticity, and convenience.

- Business owners prioritize businesses demonstrating a steadfast commitment to social welfare and environmental stewardship.
- Leveraging social media platforms for marketing endeavors can significantly amplify new products' success rates, provide vital statistical analysis and expand market reach cost-effectively.
- Embracing an agile startup ethos presents inherent advantages but is susceptible to perturbations from geopolitical and economic vicissitudes within the domestic landscape.

Lessons Learned

- Scientific methods proved to be substantial in increasing the operation efficiency as well as expediting the innovation without significant cost increment during the product development.
- Enhancing food safety protocols yielded favorable outcomes in product quality and operational efficiency, positioning the company advantageously amidst competitors and fostering market diversification.
- The likelihood of new product success heightens when a company offers a distinctive value proposition, exemplified by nutritional

Next steps

Regrettably, operations at the Solar Foods facility were suspended due to the armed conflict that commenced in Khartoum in April 2023. The immediate priority now is to rebuild the facility in a secure environment. Dr. Alaa Salih, the CEO, is steadfast in their commitment to restoring the company and fulfilling its business vision and mission in Sudan, with sights on a new location in Kassala in the eastern part of Sudan (Figure 7). Dr. Alaa is committed to transfer solar drying best practices and support the farmers to add value to their produce despite the challenges arising due to ongoing conflict in Sudan.



Figure 7. Solar Food's new location in Kassala after the destruction of the company in Khartoum State in April 2023. Photo courtesy of Solar Foods

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