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Barriers to the Use of Equipment Design Methods in West Africa

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Growth in the agricultural and agri-food processing sectors is crucial to food security and economic development in West African Countries. In Burkina Faso, local equipment manufacturers play a leading role in these fields. Furthermore, equipment design methods and tools have evolved from a linear approach to parallel engineering. Indeed, they integrate major context-specific constraints such as manufacturing, maintenance, and the user's point of view. This work aims to carry out a literature review of equipment design methods and tools applied in West African Countries, and to analyze their adoption by local equipment manufacturers. This enabled us to identify the methods and tools used, and the difficulties encountered by local equipment manufacturers in adopting them. These difficulties include: the lack of training of local equipment manufacturers the unfamiliarity and complexity of the methods and tools, and above all the unsuitability of the methods for the understanding of local equipment manufacturers, since they were initially intended for design

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teams. As a result, we were able to envisage a design approach close to local equipment manufacturers perception. Field surveys will enable us to refine this study and formalize a new, simplified approach adapted to the perception of local equipment manufacturers.

Keywords: Design tools and methods; local manufacturers; design teams; agri-food and agricultural equipment.

1. INTRODUCTION

The mechanization of agriculture and agribusiness is a major challenge for the development of West African countries (WAC). When actors in the sector need high-performance equipment adapted to local conditions, they usually turn to locally produced equipment (Medah 20211). However, while locally manufactured equipment meets the need for proximity, it often has limitations in terms of performance and reliability and according to Jacobs and Harrell (Jacobs and Harrell 1983) cited by (Afsharnia and Marzban 2020) the reliability of equipment is often linked to its design. To improve the competitiveness of such equipment and to meet the specific needs of farmers, many innovative design methods have been developed (Tarondeau 1998) highlights the diversity of design issues and the need to develop a range of adapted methods (Cavallucci 1999) lists about forty methods, of which value analysis, QFD and NPD are the most widely used. Methods specific to the context of developing countries have also been proposed, such as the CESAM method (Conception d'équipements dans les pays du Sud pour l'agriculture et l'agroalimentaire) (Marouzé 1999) or the DFMSN developed by(Bationo and Boujut 2022). The latter aims at improving the availability of equipment in small agri-food units in West Africa (Azouma et al. 2012, Azouma 2005, Azouma and Giroux 2010, Azouma and Riopel 2007, Nzie 2006) have proposed tools and methods for integrating logistics, maintenance and food hygiene and nutritional quality into equipment design (Hounsounou 2022) proposes a methodology for an integrated approach to equipment eco-design in agro-equipment manufacturing SMEs. Several other studies, in particular those (Godjo 2007,Godjo et al. 2015) and (Bationo 2007) have proposed design tools and methods to consider the user and the socio-technical network in the design process. Despite the relevance of these methods and tools, their adoption by local manufacturers remains limited. This study aim is to highlight the literature on design methods and tools used in WAC for the design and manufacture of agri-food and agricultural equipment. This study will analyze the difficulties associated with the adoption of these methods and tools, and then propose possible solutions for their acceptance by local manufacturers.

2. MATERIALS AND METHODS

First, the research question was clearly formulated: What are the barriers to the adoption of industrial engineering design methods and tools? The scope of the study was then narrowed down to the agricultural and food sector in West African countries. Databases such as Google Scholar, Scopus, Web of Science, CASSI and JSTOR were used to search for scientific journal articles and dissertations on equipment design and manufacturing. Finally, these articles were analyzed to identify the methods and tools used and any barriers to their use.

We define local manufacturers (LM) as those who manufacture, sell and/or install agro-food and/or agricultural equipment. They are able to read industrial plans and have a level of education limited to the higher diploma. Planning team: a multidisciplinary team with a level of education higher than the baccalaureate that carries out design and/or production projects.

In the rest of this article, we'll look at design methods such as the traditional method, which is defined as a sequential, structured approach to product design. It is characterized by a linear progression through defined stages with minimal backtracking. (Marouzé 1999) presents a traditional design process. Frugal design is a design approach that aims to create efficient, high-quality solutions using a minimum of resources (Weyrauch and Herstatt 2017) User-Centered Design (UCD), which places the user at the center of the development process, is a methodological approach that aims to understand users' needs, expectations, and behaviors in order to design solutions that are useful, usable, and desirable to them. The so-called agile methods, which have similarities with UCD, are new methods that are being proposed in new design projects. Initially developed for

software development, they have gradually gained ground in other fields, notably industrial engineering. Their use in industrial engineering has been tested by Mosher (Mosher et al. 2018). The Experimentation-Modification (EM) design method is an iterative approach to design in which a prototype is created, and tested under real or simulated conditions, strengths and weaknesses are identified, and necessary modifications are made before the cycle begins again. The steps are described in (Havard, 1998). According to Anderson (Anderson 2003) low cost is a strategic approach that aims to significantly reduce the cost of producing a product or service while maintaining sufficient quality to meet consumer expectations. The world of design has not remained on the sidelines of artificial intelligence, as we are witnessing the birth of generative design. This is a revolutionary approach to computer-aided design (CAD) that uses artificial intelligence and algorithms to generate multiple design options based on specific parameters and constraints. Hyunjin (Hyunjin 2020) shows the changes that the development of a generative design system will bring to manufacturing.

3. RESULTS

The following table lists 20 small-scale projects for equipment for the agricultural and agro-food sectors in West African countries.

3.1 Design Methods Used in Equipment Design Projects

The Fig. 1 shows the different design methods used in the agricultural and agro-food sector in WAC.

Table 1. listing agricultural and agri-food equipment design and manufacturing projects

No.	Equipment project	Method	Tools	Country
1	Tuber cutter (Lingani et al. 2021)	Functional analysis	Horned Beast Octopus diagram FAST CAD Prototyping	Burkina Faso
2	ATESTA Dryer (Soulama et al. 2024)	Functional analysis	Octopus diagram Functional Specifications FAST MCA CAD Prototyping	Burkina Faso
3	Grain threshers (Bationo et al. 2022)	Functional analysis	Octopus diagram Functional Specifications FAST CAO Prototyping	Burkina Faso
4	Direct seeder (Dayou 2021)	UCD	CAD Simulation Prototyping	Bénin
5	Hybrid solar dryer (Alenkhe et al. 2012)	Frugal conception	CAD Simulation Prototyping	Bénin
6	Portable maize dryer (Afriyie et al. 2023)	Traditional Method	CAD Simulation	Ghana
7	Moringa leaf dryer (Deck 2024)	Traditional Method	CAD Prototyping	Ghana
8	Hammer Mill (Mohammed et al. 2023)	Redesign	CAD Simulation Prototyping	Ghana

No.	Equipment project	Method	Tools	Country
9	Rotary roaster (Tulashie et al. 2020)	Traditional Method	CAD Prototyping	Ghana
10	Forced Convection Solar Dryer (Sakouvogui et al. 2023)	Traditional Method	Prototyping	Guinée
11	Amaranth seed drill (Sedara et al. 2020)	Low-Cost conception	CAD Prototyping	Nigeria
12	Motorized plantain slicer (Okoh et al. 2024)	Traditional Method	CAD Prototyping	Nigeria
13	Cereal Grinder (Olay et al. 2019)	Traditional Method	CAD Simulation Prototyping	Nigeria
14	Manual Hydraulic Palm Oil Press (Oghenevwaire 2021)	Frugal conception	CAD Prototyping	Nigeria
15	Bicycle Sprayer (Abdullateef et al. 2024)	Traditional Method	CAD Prototyping	Nigeria
16	Dual Function Seed and Fertilizer Spreader (Mele et al. 2021)	Traditional Method	CAD Prototyping	Nigeria
17	Dryer for pounded yam flour (Ayodeji et al. 2017)	Traditional Method	CAD Prototyping	Nigeria
18	Semi-automatic cassava planter (Ale and Manuwa 2020)	Frugal conception	CAD Prototyping	Nigeria
19	Direct seeding under vegetative cover with animal traction (Diakhate et al. 2018)	Experimentation-Modification	CAD Prototyping	Nigeria
20	Design of organic manure spreader(Azouma et al. 2007)	CESAM	Prototyping	Togo

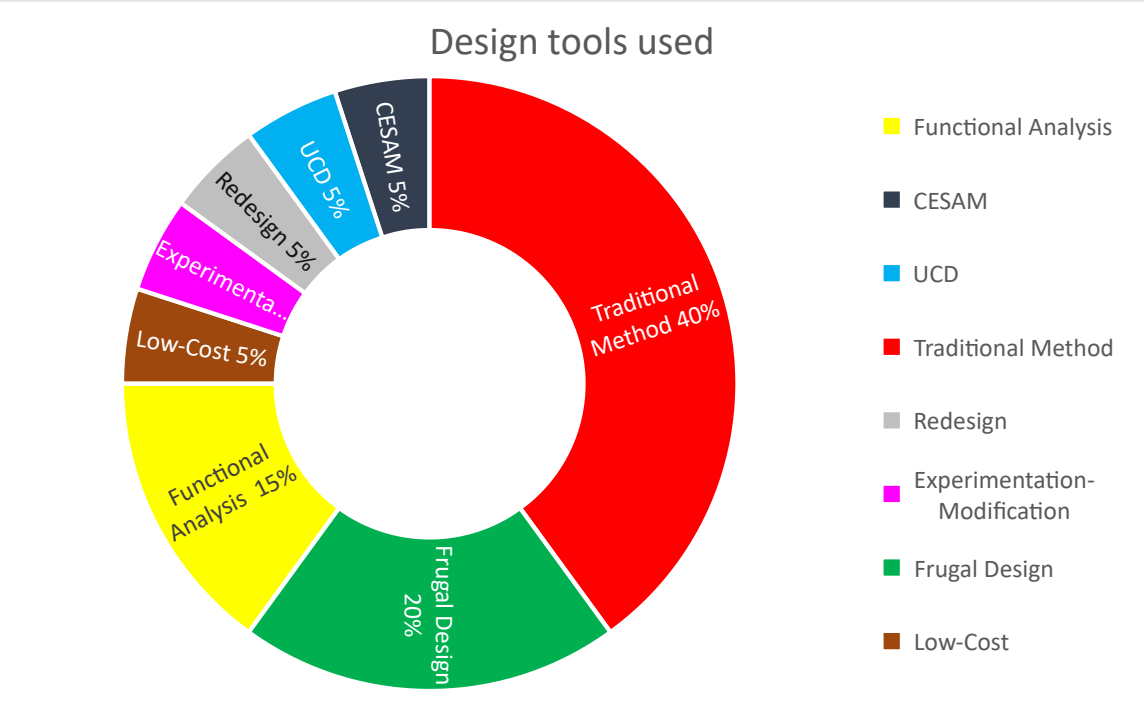

Fig. 1. Design methods used in West African countries for the design of agricultural and agri-food equipment

It clearly shows that the traditional method is the most widely used with a representation of 40%. This observation of the dominance of the traditional method had already been highlighted by (Marouzé1999) but the difference is that today we are witnessing the use, albeit timid, of other design methods such as the Frugal method at around 20%, followed by Functional Analysis at 15%, which shows that design teams are beginning to optimize the equipment development cycle. Several factors may explain this situation. First, the other methods may be less well known. Second, they may be more complex and costly to implement. Finally, these methods may not be suitable for WAC.

3.2 Design Tools Used in Device Design Projects

The figure below shows the design tools used in West African countries.

Fig. 2 shows that the most commonly used tools are prototyping and computer-aided design (CAD). The dominance of these tools can be justified by the fact that they significantly speed up the design and production processes, while reducing the costs associated with product development. What's more, they act as mediating objects (Jeantet 1998) fostering effective collaboration between design teams.

Simulation is increasingly used because design teams have a better understanding of CAD. However, tools such as the octopus diagram, Functional Specifications, and FAST are not widely used because they are likely to require more time and a multidisciplinary team, thus increasing development costs. Other design tools, such as FMEA (Bationo & Ilboudo 2023), or in general tools that use quantitative or qualitative criteria, are also little used. These criteria, which are generally measurable or evaluated, require the use of historical data, which is often not available. The question is why tools that use feedback from design teams to evaluate these criteria are not used.

The limited uptake of design methods and tools may be due to several constraints:

- Lack of awareness and lack of training. In fact, the introduction of design methods into academic training in West African countries is late. In Burkina Faso, for example, these methods are only taught as part of the university curriculum. This limits the capacity of LFs to adopt and promote these new methods.

- Complexity: Design methods can be perceived as difficult or too complex to implement, which can discourage potential users.

- Stakeholders' perceptions of these methods are a critical factor in their adoption. Fears or simple habits can act as barriers to the use of new tools.

- The cost of adopting certain design methods is a major barrier, particularly for LFs whose customers tend to have low budgets. This observation leads these manufacturers to work with limited budgets, thus limiting the use of design tools and methods.

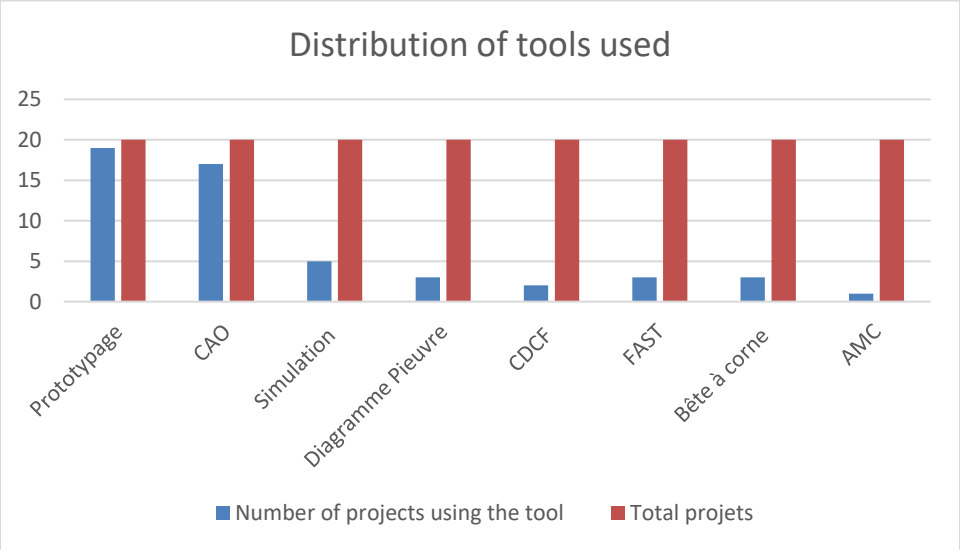

Fig. 2. Design tools used in West African countries to design agricultural and agri-food equipment

4. DISCUSSION

This work revealed a diversity of methods and tools used in the design of agricultural and agri-food equipment in West Africa published scientific papers. It also highlights the most commonly used methods and tools and shows a progression in the adoption of these tools and new design methods. Although the results are indicative of current practice, it is likely that the inclusion of unpublished work, particularly from local manufacturers, will alter these trends slightly. Nevertheless, our findings on the methods used do not contradict those of previous studies (Marouzé 1999, Azouma 2005, Godjo 2007, Bationo 2007).

Although many barriers to the use of design methods and tools have already been identified in the literature (Ngnassi et al. 2022), our study provides an exhaustive summary of these constraints. This detailed compilation makes it possible not only to establish a precise state of play, but also to identify avenues of improvement for wider adoption of these methods in our specific context, which are as follows:

-Early integration of design tools and methods into training could be considered,

- Developing design methods and tools that are more intuitive and easier to use,

- Developing communication campaigns to promote the benefits of design methods and demonstrate their effectiveness.

-Encouraging networking between professionals in the field to create a community for sharing and exchanging good design practice.

These solutions could form the basis of future research to facilitate the use of design methods and tools by local manufacturers.

5. CONCLUSION

Our study revealed that the majority of agricultural equipment designs in West Africa are based on the traditional method (40%), followed by frugal design (20%) and functional analysis (15%). It should be noted that prototyping and computer aided design (CAD) are the most commonly used tools in design projects. Despite these advances, the adoption of modern methods is still limited by a lack of training, the perceived complexity of the methods and financial constraints. This study also opens up perspectives for future research, in particular on the adaptation of design methods to the constraints and realities of local manufacturers.

Finally, the next step will be to conduct an exploratory field study to analyze unpublished work and the evolution of equipment design in order to optimize these approaches and make them more accessible to local actors. This will require close collaboration between researchers, local manufacturers and training institutions to develop solutions tailored to the specificities of the West African context.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abdullateef, A. A., Lawal, S. S., Aliyu, Y., Kehinde, O. T., & Dickson, S. (2024). Design and fabrication of a bicycle sprayer. *ABUAD Journal of Engineering Research and Development, 7*(1), 278-287.

Afriyie, D., Akorli, J., Boadi, K., Amediku, S., & Berko, N. (2023). A portable design of a maize drying machine. *Science Engineering Entrepreneurship Design (SEED) Journal, 2*(1).

Afsharnia, F., & Marzban, A. (2020). Investigating the long-term effect of preventive maintenance strategy on the operational efficiency and failure rate of sugarcane harvester using time series. *Journal of Agricultural Machinery, 10*(2), 347-359. Available:https://doi.org/10.22067/jam.v10i2.70962

Ale, M., & Manuwa, S. (2020). Design and fabrication of a semi-automatic cassava planter. In *IOP Conference Series: Earth and Environmental Science, 445*(1), 012002. IOP Publishing.

Alenkhe, E., Onadipe, O., & Sanni, L. O. (2012). Solar drying technology: A pilot design in Benin Republic.

Anderson, D. M. *Design for manufacturability & concurrent engineering: How to design for low cost, design in high quality, design for lean manufacturing, and design quickly for fast production*.

Ayodeji, S. P., Ajamu, T. A., Akinnuli, B. O., &Aderoba, O. A. (2017). Development and performance evaluation of an effective dryer for poundo yam flour processing plant. *Cogent Engineering, 4*(1), 1293481. Available:https://doi.org/10.1080/23311916.2017.1293481

Azouma, Y. O. (2005). *Integration of manufacturing and maintenance in a multidisciplinary design approach for agricultural and agri-food equipment for Africa* (Doctoral thesis). Besançon. Available:https://theses.fr/2005BESA2006

Azouma, Y. O., & Riopel, D. (2007). *Fully integrated logistics for the design of agricultural and agri-food equipment for Africa*. CIRRELT.

Azouma, Y. O., Giroux, F., &Varchon, D. (2007). Conception d'un épandeur de fumuresorganiques pour les exploitations à traction animaled'Afrique. *Tropicultura, 25*.

Azouma, Y. O., & Giroux, F. (2010). Maintenance Integration in Equipment Design Process for Africa. Bangladesh Journal of Scientific and Industrial Research, 44. https://doi.org/10.3329/bjsir.v44i3.4405

Azouma, O. Y., Awesso, E. P., & Bawa, M. L. (2012). Integration of hygienic and nutritional quality of food during the design of agri-food equipment. *Sciences Naturelles et Appliquées, 4*(1 & 2). Available:https://revuesciences-techniquesburkina.org/index.php/sciences_naturelles_et_appliquee/article/view/586

Bationo, F. (2007). *Proposal of a collaborative maintenance-oriented equipment design approach: The case of small agri-food processing units in Burkina Faso* (PhD thesis). Institut National Polytechnique de Grenoble - INPG. Available:https://theses.hal.science/tel-00419294

Bationo, F., & Boujut, J. F. (2022). Design for the socio-technical maintenance network. *AMA*, 53(10).

Bationo, F., et al. (2022). Integration of the grinding function with a cereal thresher for the recovery of crop residues in composting. *International Journal of Advanced Research, 10*(11), 105-117. Available:https://doi.org/10.21474/ijar01/15646

Bationo, F., & Ilboudo, A. Z. (2023). Experimentation of the Failure Mode Analysis method of their Effects and Criticalities: Case of a network of maintenance actors. https://jsaer.com/download/vol-10-iss-9-2023/JSAER2023-10-9-106-115.pdf#page=8.25

Cavallucci, D. (1999). Contribution to the design of new mechanical systems by methodological integration. Université Louis Pasteur (Strasbourg).

Dayou, E. D. (2021). Design, fabrication and assessment of direct seeder in Benin Republic. *Agricultural Engineering International: CIGR Journal, 23*(1), 138-147.

Deck, B. (2024). Moringa Connect: Design and fabrication of the drum for a Moringa leaf dryer prototype.

Diakhate, D., Havard, M., Ralisch, R., Fall, A., & Sarr, I. (2018). Un semoir de semis direct sous couvertvégétal à traction animaleadapté aux conditions du Sénégal (pp. 217-220).

Godjo, T. (2007). *Development of a user-oriented design method: Case of tropical agri-food equipment* (PhD thesis). National Polytechnic Institute of Grenoble - INPG. Available:https://theses.hal.science/tel-00413121

Godjo, T., Boujut, J.-F., Marouzé, C., & Giroux, F. (2015). A participatory design approach based on the use of scenarios for improving local design methods in developing countries.

Havard, M. (1998). Experimentation and design of animal-drawn equipment in developing countries: The case of the nematicide Stericulturist in Senegal.

Hounsounou, J. (2022). *Proposal of a method for an integrated approach to eco-design of equipment in SMEs of agro-equipment manufacturing in Benin* (PhD thesis). University of Abomey-Calavi (Benin). https://hal.science/tel-03747022

Hyunjin, C. (2020). A study on application of generative design system in manufacturing

process. *IOP Conference Series: Materials Science and Engineering, 727*, 012011. Available:https://doi.org/10.1088/1757-899X/727/1/012011

Jacobs, C. O., & Harrell, W. R. (1983). *Agricultural power and machinery*. Gregg Division, McGraw-Hill.

Jeantet, A. (1998). Les objetsintermédiaires dans la conception: Éléments pour unesociologie des processus de conception. *Sociologie du travail*, 291-316.

Lingani, H. A. K., Ye, G. S., & Kam, S. (2021). Sizing of a tuber cutter integrated into the value chain of. 33(1).

Marouzé, C. (1999). Proposal of a method to steer the technological trajectory of equipment in the countries of the South: Application to the agricultural and agri-food sector. Paris: ENSAM.

Marouzé, C., & Giroux, F. (1998). Méthode CESAM : Conception d'équipements dans les pays du Sud pour l'agriculture et l'agroalimentaire, méthode. Modèle 1.2 en date du 9 juillet 1998. Evolution de la méthode par rapport au premier modèle du 15/10/97. Document de travail [monograph]. https://agritrop.cirad.fr/315202/

Medah, I. (2011). *Social dynamics of collaboration, trust and recognition at the heart of the agricultural equipment design process in West Africa: The case of Burkina Faso* (PhD thesis). University of Grenoble.

Available:https://theses.hal.science/tel-00630661/

Mele, E., Diraso, B., Dauda, D., & Bulama, M. (2021). Design, construction and evaluation of a dual operation seed and fertilizer broadcaster for farmers.

Mohammed, A.-H., et al. (2023). Redesign and simulation of a hammer mill to minimize consumption of iron filings. *International Journal of Mechanical Engineering, 8*.

Mosher, T. J., Kolozs, J., & Wilder, E. Agile hardware development approaches applied to space.

Ngnassi, D. A. B., Nzié, W., & Doka, Y. S. (2022). Facteurs Limitants l'Application des Méthodes de Conception Adaptées a l'Usage dans le Contexte des Pays du Sud: Cas du Cameroun. European Scientific Journal, ESJ, 18(33). https://doi.org/10.19044/esj.2022.v18n33p263

Nzié, W. (2006). *Integration of maintenance in design: Application to agri-food equipment* (Doctoral thesis). Besançon. Available:https://theses.fr/2006BESA2001

Oghenevwaire, I. (2021). Design and fabrication of a manual hydraulic palm oil press machine using locally sourced materials. *FUPRE Journal of Scientific and Industrial Research (FJSIR), 5*(1), 13-25. Available:https://journal.fupre.edu.ng/index.php/fjsir/article/view/121

Okoh, P. A., Eze, J. N., &Ademiju, T. A. (2024). Design and fabrication of improved motorized plantain slicing machine for chips production. *World Journal of Advanced Engineering Technology and Sciences, 11*(1), 395-401. Available:https://doi.org/10.30574/wjaets.2024.11.1.0070

Olay, M., Is, A., & Yahaya, M. E. (2019). Design of cereal crops crushing machine. *Scientific Journal of Engineering and Technology, 7*(5). Available:https://doi.org/10.21276/sjet.2019.7.5.5

Sakouvogui, A., Barry, T. A., Sakho, A. M., & Keita, M. (2023). Experimentation of a forced convection solar dryer for drying sweet potatoes at the Higher Institute of Technology of Mamou-Guinea. *World Journal of Engineering and Technology, 11*(3), 536-548.

Sedara, A., Ibrahim, Y., Manuwa, S., &Sedara, O. (2020). Development of a low-cost seed drill for sowing amaranth seed. *Agricultural Engineering International: CIGR Journal*, 39-45.

Soulama, Y., Bationo, F., & Tapsoba, F. (2024). Evaluation of the performance of the ATESTA forced convection dryer when drying pineapples. *Indian Journal of Science and Technology, 17*(14), 1252-1262.

Tarondeau, J. (1998). *Industrial strategy*. Collection Gestion, Vuibert.

Tulashie, S. K., Appiah, G., Akpari, E. E. A., &Saabome, S. M. (2020). Design of shea nut rotary roasting machine used for shea butter production in Ghana. *International Journal of Thermofluids, 1-2*. Available:https://doi.org/10.1016/j.ijft.2020.100015

Weyrauch, T., &Herstatt, C. (2017). What is frugal innovation? Three defining criteria. Journal of Frugal Innovation, 2(1), 1. Available:https://doi.org/10.1186/s40669-016-0005-y

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