Environmental life cycle assessment of cowpea production, 
storage and disposal in Ilorin, Kwara State, Nigeria

O C Ogunjirin¹*, S O Jekayinfa², J A Olaniran² and O A Ogunjirin³

¹Department of Postharvest Engineering Research, Nigerian Stored Products Research 
Institute, P.M.B 1489 Ilorin, Nigeria.
²Agricultural Engineering Department, Ladoke Akintola University of Technology, 
Ogbomoso, Oyo State.
³Engineering and Scientific Services Department, National Centre for Agricultural 
Mechanization, Ilorin, Nigeria.

*Corresponding author e-mail address: omololaogunjirin@gmail.com

Abstract. Life cycle assessment (LCA) was developed to estimate the environmental impacts of 
industrial production processes and systems. This paper assessed the environmental impacts 
associated with the production, storage and disposal of cowpea grains in Ilorin, Kwara state, Nigeria, 
and proffer ways of improving and reducing some of the environmental impacts associated with the 
system. Three scenarios were created in the cowpea study; production and storage in an inert 
atmosphere silo, hermetic storage, and cold shock (freezer) storage respectively. The inventory data 
obtained from the scenario was analysed using Gabi 8.7 think step 2018 version. From the cradle-
to-grave research study and Centre of Environmental Science (CML) methodology used, it was 
obtained that the Global Warming Potential (GWP) for the three scenarios were 6.7, 6.46, and 8.82 
kg CO₂-equivalent for inert, hermetic and cold shock respectively. Acidification Potential (AP) 
values for the three scenarios were: 0.0105, 0.01 and 0.0121kgSO₂ equivalent respectively, 
Eutrophication Potentials (EP), were 1.68, 1.56, and 2.012e-3kg phosphate equivalent respectively. 
Ozone layer depletion potential (ODP) gave same values each in the scenarios with 9.99e-13kgR11 
equivalent, and human toxicology potential (HTP) values for each were 0.181, 0.151 and 0.24kg 
DCB equivalent respectively. Diesel and petrol fuel used for tillage and post farm operations 
respectively were major hotspots in the scenarios. Based on the emissions value and characterization 
factor from each scenario, inert storage and hermetic storage are recommended for 
environmentally 
friendly storage over cold shock storage in the cowpea scenario.

1. Introduction
Environment is the sum of all that surrounds a living organism, including natural forces and other living 
things which provide conditions for development, growth, danger and damage [1]. It includes water, air, 
land and the interrelationships which exist among and between them, human beings and other living 
creatures such as plants, animals and microorganisms [2]. Environmental means to be connected with, or 
relating to the surroundings in which a person or animal lives. In recent years, scientists have been carefully 
examining the ways that people affect the environment and discovered that human activity caused damage
either directly or indirectly to the environment. All agricultural activities have impact on the environment, and the environment on the other hand also has impacts, each person has an impact on the environment and the world in which we live in by growing food and raising animals using resources from the earth [3]. The effect of these activities had resulted into serious environmental damage and the notorious consequence is global warming, whereby the global temperature of the earth has been increasing markedly due to the release of specific gases into the environment. This temperature rise has led to extreme changes of climate and the eventual rise of the temperature of the seas, endangering thousands of species, including human beings.

Life Cycle Assessment (LCA) is a framework originally developed to assess the environmental impact of industrial production systems, and to examine the effect of changes to the system. The application of LCA in recent years has included the assessment of the environmental impact of agricultural systems for the production of food, fibre and fuel [4]. As indicated by the name, LCA usually examines the entire lifecycle of a product from production to disposal (cradle-to-grave). According to [5], data included in a cradle-to-grave grain crop model includes the production, transport and use of all inputs (e.g. herbicide, fertilizer, fuel) and the area of land required to produce the crop. LCA model generally examines the impact of producing a functional unit (e.g. a ton of grain).

A number of ISO standards relevant to LCA are available. ISO 14044:2006 and ISO 14071:2014. Compliance with the ISO standards provides the rigour and transparency required for end users to have a high level of confidence in the results of the LCA study [6]. In LCA methodology, four different phases can be distinguished [7]. The phases include, goal definition and scoping; inventory analysis; impact assessment; and improvement assessment (or “interpretation”) as shown in figure 1. The first LCA phase, goal definition and scoping, involves defining the purpose of the study, its scope, data quality goals, and functional unit. The functional unit is the unit of analysis defined for the study; it is defined according to the service delivered by the system under analysis. At the inventory analysis phase, the environmental burdens (or “interventions” according to ISO 14040 terminology) associated with the life cycle for the functional unit are quantified. These are the material and energy inputs and product, waste, and emission outputs to air, water, and land. During the impact assessment phase, the environmental burdens calculated in the analysis are “translated” into environmental impacts using LCA software like Gabi and Simapro, [8].
Figure 1. Diagrammatic illustration of Life Cycle Assessment methods [6].

The processes considered in the study are shown in figure 1. They include all input in the production; fertilizer and pesticide; agricultural machinery; maintenance and storage; on-farm activities; and soil-related processes. Careful modelling using LCA software was necessary in order to account for all the relevant aspects of impact.

Consumers are increasingly becoming interested in the provenance of the food they eat [9]. Provenance includes the origin of the food, its safety and nutritional value, and increasingly the environmental impacts of the production system adopted in producing and delivering the food. In response, food companies have developed management systems to track the origin and quality of the food products they manufacture, from the cradle to grave with management systems like (SQF 2000 and ISO 9000 series). Leading food companies like Nestle, Kings are looking at ways to include environmental information in their product management systems [10]. The major bottlenecks for doing so are the unavailability and incompatibility of environmental information from different sources. There is a need for transparent environmental information on food production and processing to allow food producers to select between alternative food ingredients or commodities from different production locations and to drive industry efforts towards eco-efficiency improvements. Similar studies have been reported in literature for Cassava starch production [11]; Cassava flour processing [12]; wheat production [13][14] and soybeans production and processing system into soy oil [15].

The aim of this study is to assess the environmental life cycle of cowpea’s production, storage and disposal in Kwara State, Nigeria; while the objectives are:

i. To take inventory of material usage and flow in the production, storage and distribution of cowpeagrain in Kwara State, Nigeria.

ii. To determine the environmental impact associated with the various production and storage processes using (LCA) model,

iii. To identify the steps in the food chain that have the largest impact on the environment in order to suggest improvement efforts.

2. Materials and Methods

2.1 Study Location

The locations of this study are National Centre for Agricultural Mechanization (NCAM) Ilorin, (8°26’N4°30’E) Kwara State, Nigeria and Nigerian Stored Products research Institute (NSPRI), Km. 3, Asa Dam Road Ilorin, (8°22’N4°41’E) Kwara State, Nigeria. The two institutions are research institutes whose mandate is in line with grains production, and have available machineries and technologies in grain production and storage in Nigeria.

Grains selected for this study was cowpea (Vigna unguiculata). The grain was randomly chosen from lists of available grains by 10 selected panellists and from the result of the panellists, cowpea top the list. The grains have its production source from National Centre for Agricultural Mechanization (NCAM) Ilorin, Kwara State, Nigeria, and its storage in Nigerian Stored Products Research Institute, Ilorin, and disposal at Ago market, Ilorin, Kwara State.

2.2 Experimental procedures

The research was conducted in accordance with international standards organization (ISO) procedural framework for performing LCAs in the ISO 14044 series. The inventory data collected is analysed using GABI 8.7 thinkstep software, 2018 version.

2.2.1 System boundary. The cowpea grain production, storage and disposal chain were divided into 3 stages i.e. pre-farm, on-farm and post-farm operations with input, output and associated emissions as shown in figure 2. The system boundary covers land preparation using tractor mounted with implement like disc plough, disc harrow and disc ridger. This operation was followed by planting, fertilizer application, weed control and crop protection using tractor mounted implement like seed planter, boom sprayer, and fertilizer
After the cowpea is matured, manual labour was used for the harvesting. Threshing and grain cleaning were done using multi-crop thresher. The cowpea grains were later transported to NSPRI, Ilorin for storage. After satisfying storage conditions with 12% moisture content, dry basis, and very clean, 1000kg grain was loaded into an inert atmosphere silo for storage using mechanically powered screw conveyor and the cowpea grain was stored for four months during which the storage maintenance that is, purging (introducing nitrogen gas into the silo bin) was carried out. The grains were offloaded using screw conveyor powered with petrol engine and were discharged into a collector (bunker). The second storage method scenario is the hermetic storage in which 1000 kg cowpea grain was bagged with 20 units of 50 kg polypropylene - lined with polyethylene bag. Also for the third scenario, 1000 kg is bagged with 20 units of polyethylene bag and stored in a 3 units of 340kg capacity (Samsung) freezer compartment. The grains were also stored for four (4) months after which the grains were emptied into a bunker. From the bunker the grains were bagged into 25 kg and 50 kg bags, weighed and sewn using electric weighing balance and electric sewing machine respectively. The bagged cowpea grains were transported to Ago market in Ilorin using petrol engine double cabin truck for disposal (distribution) to consumers.

2.2.2 The Scenarios created. In order for inventory data (All the input into the cowpea production, storage and disposal) shown on Table1 to be inputted into the Gabi software, three scenario were created for the cowpea grain selected for this study. Scenario creation allows you to compare the impact of different system configurations/conditions. Any number of parameters can be selected to create a scenario and this can be compared directly with other scenarios.

Scenario for cowpea as shown in figure 3(a and b) includes:

i. Cowpea production and storage in inert atmosphere silo
ii. Cowpea production and storage using hermetic storage (polypropylene lined with polyethylene bag).
iii. Cowpea production and storage using cold shock (freezer)
**Figure 2.** System boundary of cowpea production, storage and disposal
2.2.3 Environmental impact assessment methods of the grain production, storage and disposal processes. There are different methods that could be used to perform a Life Cycle Impact Assessment. These methods are continuously researched and developed by different scientific groups based on different methodologies. The method used in this research project was Centre of Environmental Science, University of Leiden, the Netherlands (CML).

There are different impact categories in life cycle project, but for this research work, five impact categories were selected which includes: global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), ozone layer depletion potential (ODP), and human toxicological potential (HTP).

The sum of inventory of resources consumption in the production, storage and disposal of the sorghum grain system of study is presented in table 1, all the basic grain production operations involved the use some source of energy from land preparation to harvesting to storage and disposal. The use of direct energy in form of fossil fuel (diesel) was involved in land preparation stage which include ploughing, harrowing, and planting, for ploughing operation 10L/ha was used, harrowing was 9L/ha and ridging was 10L/ha. An appropriate implement attached to a 4-wheeled tractor is used for land preparation operation. Crop protection operation involved the use of synthetic fertilizer and it involves the use of 25kg NPK fertilizer 15-15-15 to boost the yield of grains. Cowpea grain was planted with a spacing of 75cm by 50cm, 1-2 grains per stand and population density of 80,000ha, 25kg of grains is required to plant 1 hectare of land to give an average yield of as much as 1.5 – 3tons/ha on a well-maintained soil with best cultural practices [15]. Table 2 shows the result of the environmental impact of the cowpea grain process studied and the result is represented using CML (2015) methods from GABI.

| S/No | Total Items Used | Quantity | Comment |
|------|------------------|----------|---------|
| 1.   | Diesel Fuel      | 51.5 ltrs | Fuel used for ploughing, harrowing, ridging, planting, spraying 1 hectare of land. |
| 2.   | Human labour     | 53 man hr. | Human labour used in operating mobile and stationery machines and implement used, manual harvesting, grain bagging, grain weighing, chemical mixing, purging of silo etc. |
| 3.   | Petrol Fuel      | 40 ltrs  | Fuel used for threshing operation, for pickup van transportation, for stationery operations to power grain conveyor for 1,000kg (1 ton) of grain. |
| 4.   | Electricity      | 25kw/hr. | Electric power consumed in grain weighing, sewing of bag, freezer (cold shock), and for operating mixer and grinder. |
| 5.   | Grains (cowpea)  | 25kg each | Grain used for planting 1 hectare of land. |
| 6.   | Nitrogen gas     | 12kg (cylinder) | Nitrogen gas for purging the silo. |
| 7.   | Deep freezer     | 3 units of 340ltrs capacity | For the cold storage of grains |
8. **Chemicals**
   - Herbicide (pendelin)
   - Insecticide (Labdaca)
   - 1.5 ltrs
   - 1.5 ltrs
   - Chemicals for weed control, cowpea pod insecticide

9. **Packaging Materials**
   - Polypropylene bag
   - Polyethylene bag
   - 50kg (40pcs)
   - 50kg (20pcs)
   - For hermetic storage and packaging to market

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**Figure 3a.** Screen display for GaBi (cowpea scenario)
3. Result and Discussion

Table 2. Cowpea result for CML method

| IMPACT CATEGORIES | Characterization Factor | INERT  | HERMETIC | COLD SHOCK |
|-------------------|-------------------------|--------|----------|------------|
| Kg CO₂ equivalent | 6.7                     | 6.46   | 8.82     |
| Kg SO₂ equivalent | 0.0105                  | 0.01   | 0.0121   |
| e-3kgPhosphate equivalent | 1.68                  | 1.56   | 2.04     |
| e-13kgR11 equivalent | 9.99                   | 9.99   | 9.99     |
| Kg DCB equivalent | 0.181                   | 0.155  | 0.246    |
3.1 Global Warming Potential (GWP)

The characterization factor for the CML method of assessment is Kg CO₂ equivalent for global warming. The impact value obtained from the Inert storage is 6.7, Hermetic is 6.46 and cold shock is 8.82 respectively. Based on the characterization factor of Kg CO₂ equivalent, cold shock contributed largely to global warming potential with 8.82 Kg CO₂ equivalent in the cowpea scenario as shown in figure 4.

3.2 Acidification Potential (AP)

The characterization factor for CML method in the contribution to acidification potential in the cowpea scenario is kgSO₂ equivalent. The impact value obtained from inert is 0.0105, hermetic is 0.01 and cold shock is 0.0121 kgSO₂ equivalent. From the contribution to acidification potential in the cowpea scenario, cold shock gives the highest contribution of 0.0121 kgSO₂ equivalent as shown in figure 5.

Figure 4. Global warming potential for cowpea scenario
3.3 Eutrophication Potential (EP)
The characterization factor for CML method in the contribution to Eutrophication potential in the cowpea scenario is e-3kg phosphate equivalent. The impact value obtained from inert is 1.68, hermetic is 1.56 and cold shock is 2.04 e-3 kg phosphate equivalent respectively. From the contribution to eutrophication potential in the cowpea scenario, cold shock gives the highest contribution based on e-3kg phosphate equivalent with 2.04, as shown in figure 6.

3.4 Ozone Layer Depletion Potential (ODP)
The characterization factor for CML method in the contribution to Ozone layer depletion potential in the cowpea scenario is e-13kg R11 equivalent. The impact value obtained for the ozone layer depletion potential from inert, hermetic and cold shock were the same values and it gave 9.99e-13kg R11 equivalent for each scenario. From the contribution to ozone layer depletion potential in the cowpea scenario, the three scenarios contributed equally with 9.99 e-13kg R11 value for each scenario as shown in figure 7.

3.5 Human Toxicology Potential (HTP)
The characterization factor for CML method in the contribution to Human toxicology potential in the cowpea scenario is kg DCB (dichlorobenzene) equivalent. The impact value obtained from CML for the human toxicology potential from inert is 0.181, hermetic is 0.155 and cold shock is 0.246kg DCB equivalent respectively. From the contribution to human toxicology potential in the cowpea scenario, the CML method value for each of the scenario gives higher value based on kg DCB equivalent of 0.181 for inert, 0.155 hermetic and 0.246 for cold shock respectively as shown in figure 8.
Figure 6. Eutrophication potential for cowpea scenario

Figure 7. Ozone depletion potential for cowpea scenario
4. Conclusion

From the results obtained in this research work, the following conclusions can be drawn:

It was discovered that diesel and petrol (fuel) used in the tillage and in stationery operations were major hotspots during the cowpea production. The Gabi software used in analysing this work identified impact value of 0.0121 kg SO$_2$ equivalent under acidification potential as 10% greater than base scenario. The drive to enhance sustainable grain production and storage by Nigerian government will result to greater environmental burden which becomes a great concern for stakeholders in environmental industry and considering the scenario created for the cowpea production, storage and disposal, the cold shock scenario is the most expensive in terms of economy, due to electric power consumption and augmenting power failure with generator usage during storage. Therefore, for environmentally friendly storage, the inert and hermetic storage is recommended over cold shock storage.

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