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Design of a Smoker-Dryer for Chicken

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Abstract

Chicken breeders, particularly those in Ngaoundéré-Cameroon, after 45 days of breeding find themselves confronted with the problems of wasting nutrients and resources. In most cases, they sell their chicken at low prices to avoid expenses. Faced with these problems, a few of them use various methods to preserve their chicken after 45 days of breeding, including cold preservation, smoking and drying. Cold preservation is the most widely used technique, but this technique is energy-intensive, without forgetting the untimely power cuts, and the deterioration of the quality of the product. By getting closer to its stakeholders, we were able to identify their difficulties, why they use cold preservation more and they also entrusted us with the characteristics of equipment that could meet their requirements. In this article we presented the results from functional analysis to 3D modeling through the search for solutions to resolve contradictions. It emerges from this study that the designed model guarantees food safety, user safety, retains all nutrients, ergonomic, uses fewer resources, fast, adaptable to any type and size of smoking products and that it is possible to achieve it industrially.

Keywords: Design, smoker, dryer, modelization, Triz

Introduction

Chickens are used as one of the best sources of animal protein for low-income populations and are therefore receiving increasing attention worldwide. The interest in these is booming, it is mainly influenced by the global quest to satisfy the needs of meat products of the inhabitants which continues to increase. Furthermore, it is well known that currently there are few technical alternatives to meat products for their nutritional contributions in the human body. Hence the increasing attention devoted to chicken as the best source of animal protein and low fat.

In Cameroon, and even in the world, the vast majority of the chicken production chain is sold after 45 days of breeding. However, a weak Link remains: conservation given that it is a product with a high-water content which decomposes quickly after slaughter. If conservation equipment exists, such as refrigerators, dryers, smokers, etc., they do not allow peaceful processing to take place without altering the quality of the finished product, without making consumers and processors sick.

In fact, cold storage has the disadvantage of being supplied with electrical energy throughout the storage period and consumes excessive electrical energy; drying and smoking are both painful and degrade the quality of the finished product, leads to losses of around 50%, a waste of time and resources. Hence the need to develop a necessary system for conservation that guarantees food safety and improves the conditions of processors.

With this in mind, the main objective of this work is to design chicken smoking-drying equipment taking into account the requirements of future users. More specifically we will have to determine the physical properties of chicken meat, analyze the needs and model the process.

Literature review

Poultry meat is the one whose consumption is increasing the fastest in the world since the 1970 to the point where it became the most consumed meat in the world in 2016 and allows global consumption to double. The FAO estimates that the consumption of poultry meat should increase by 120% between 2005 and 2050, which can be explained by a demographic effect and an increase in per capita consumption, which would have increased from almost 8kg/inhabitant at the beginning of the years 2000 to almost 13kg/Inhabitant in 2021. Chicken plays a leading role in this evolution thanks to its undeniable advantages such as: accessibility, economic advantages, environmental advantages, the absence of religious prohibitions, quality and nutritional value of products, particularly due to the low-fat content, Sénat (2022). The preservation of poultry meat or any other meat product in some countries of the world is very difficult due to the lack of electrical energy and unexpected power cuts, hence the development of traditional and less expensive preservation techniques such as: smoking, drying, salting, frying or fermentation and many others. Processes like smoking and indirect drying present a wide variety of physicochemical parameters, therefore, a wider choice for consumers. The many types of smoked and dried foods are highly valued food products, for which these processes have helped to extend shelf life, quality and achieve the flavor and texture required by consumers. Extending shelf life can also affect the nutritional value of foods, such as vitamin content, CAC/RCP (2009).

Going in the same direction, several studies have emerged in the field of smoking and drying with the aim of improving, ensuring health safety for smoked products and providing the necessary information linked to a good quality product. Indeed, for Vierling (2003), meat is an element that provides many nutrients essential to a balanced diet. It is a source of excellent quality proteins because these proteins contain 40% essential amino acids. This food also provides minerals such as phosphorus, iron, etc. and also vitamins from group B. The lipid content is 1 to 3% in white chicken meat, which is therefore particularly interesting provided that the skin, which has a high lipid content, is excluded.

For Hamdani (2018), poultry meat represents an important source of high-quality protein (balanced amino acid content) which gives it significant nutritional value even in small quantities. Poultry meat contains 72.7% water, 26.6% proteins of high biological value. It contains approximately 6% fat in the form of lipid deposits in the skin and inside the abdominal cavity. It also contains mineral elements poor in iron but rich in sodium and potassium (The most representative vitamins in chicken meat are: Vitamins AB PP and vitamin C, the latter is destroyed during cooking.

Nutritionists agree that the balance of the different fatty acids present in poultry is close to the perfect balance: 25% saturated fatty acids (SFA), 55% monounsaturated fatty acids (MUFA), the latter reduce the level of bad LDL cholesterol and 20% of polyunsaturated fatty acids (PUFA), Roger (2011). However, chicken meat provides appreciable quantities of PUFA, vitamins (B3, B5, B6, B12, etc.), minerals and trace minerals (iron, magnesium, selenium, phosphorus) and good quality proteins rich in essential amino acids, necessary for muscle growth, particularly in children and adolescents, but also essential for maintaining muscle mass in the older people Roger (2011). Like all meats, it does not contain carbohydrates. Table 1 below shows the chemical composition of chicken proposed by Ciqual (2007).

Table 1. Chemical composition of chicken (Ciqual, 2007)

For 100 g of meat	Water (g)	Energy (kJ)	Protein (g)	Lipids (g)	Cholesterol(mg)
Raw thigh, meat and skin	70	832	17	14.8	90
Roasted thigh, meat and skin	59	962	26	14.2	122
Raw meat and skin	69	738	18	11.6	80
Roasted meat and skin	66	678	26	6.2	90
Raw white	72	489	22	2.9	61
Cooked white	73	523	22	3.9	71

Methods

To achieve our objective of designing a smoker dryer for chicken taking into account the requirements of the stakeholders, we used some tools such as the 40 principles of invention, the 39 parameters of Triz, etc. And several methods in particular: Triz method, the Lean Scienspreneur method, functional analysis… some of which we will present in the following lines. For Perrin (2001), a design method is any procedure and techniques used by designers during the process of designing a new product.

Analyze the need

A product only makes sense if it satisfies the user's needs. In other words, we must clearly pose the problem, that is to say define the why of the product? what is it used for? Who does he serve? and for what purpose? before imposing a how? or even a solution as brilliant as it may be which will probably not meet the user's needs. The objective of analyzing the need is to grasp, state and validate the requirements expressed by the actors.

Capture the needs

In this phase, it is a question of making a trip to the field in order to know their needs on an economic, ergonomic and other level. We can use several tools including the 5 whys, survey sheets, etc.

State the needs

This involves rigorously expressing the goal and limits of the studies. To do this, the Horned Beast tool can be used to clearly state needs by providing answers to the following questions:

- Who or what does the product serve?
- Who or what does the product work on?
- What purpose?

Validate needs

After having clearly identified the need to be satisfied by the product, it is necessary to check its stability. To do this, it is necessary to find out whether this need is likely to disappear or evolve over a longer or shorter period of time. This validation check consists of providing answers to the following questions:

- Why does this need exist?
- What can make it disappear, make it evolve?
- What is the risk of making it disappear?

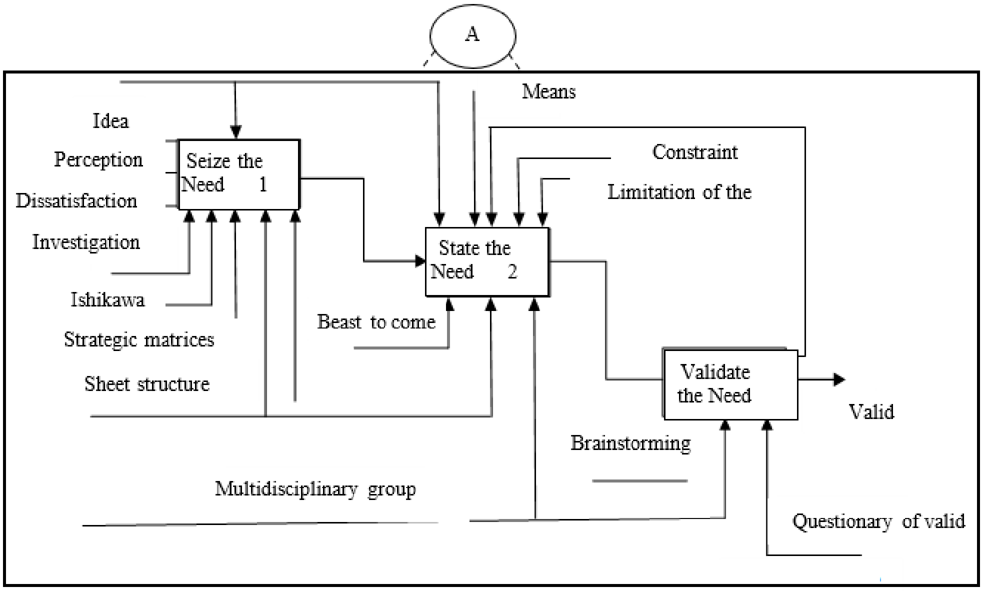

Figure 1. Needs analysis framework

Study the feasibility

It is the functional expression of the need. In fact, its objective is to establish the functional specifications (CdCF). In this phase, it is necessary to identify and explain the satisfactions expected by users of the product. The CdCF is considered as a generator of service functions (FS). Therefore, at the end of this phase, it is necessary to identify, characterize and prioritize the FS.

Identify service functions

This involves determining the relationships that external elements maintain with each other through the equipment on the one hand, and the interactions they carry out with the environment on the other hand. The Octopus diagram tool can facilitate identification of equipment service functions.

Characterize service functions

In this phase, the aim is to express the performance of each service function, expected by the user, which can be collected during the field trip phase (requirements capture). For each function this will be:

- To state the assessment criteria for each FS (an assessment criterion represents a requirement desired by the user. A level defined in a scale adopts the value of the criterion, it is accompanied by flexibility (high tolerance) beyond of which the need is declared unmet.)
- To define the level of each criterion
- To match each criterion with flexibility

Prioritize Service Functions

This involves comparing functions one by one using a matrix and assigning a score which can be collected during surveys with future users. Then quantify the weight of each function in order to establish a histogram in order to make the prioritization results meaningful.

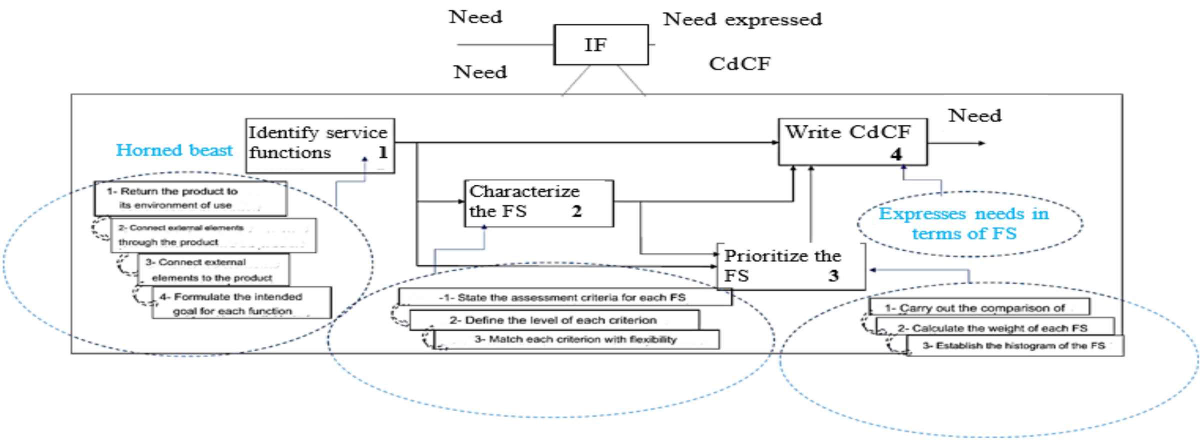

Figure 2. Feasibility study structure

Design and Define

In this phase, it is:

- Search for ideas and solutions: which consists of transforming all validated service functions into contradictions and reporting them in the Triz contradiction resolution matrix in order to identify the principles for solving problems using the 40 invention principles.

- Study and evaluate the solutions: which consists of searching for the optimal solution among the 120 suggestions offered by the 40 principles of inventions.

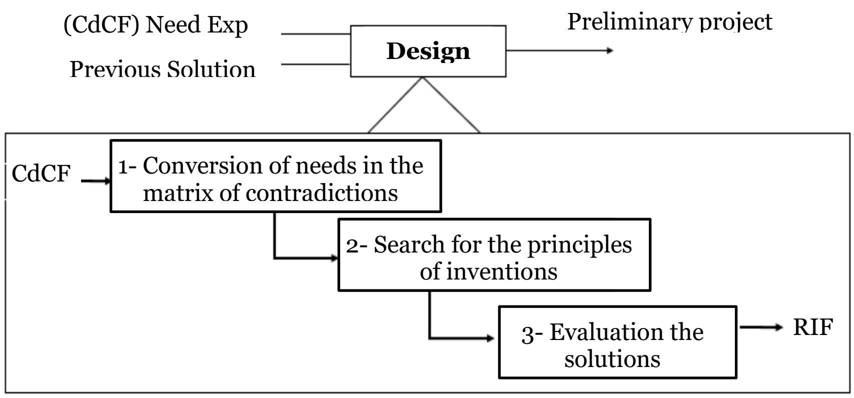

Figure 3. Design structure

Results

Analysis of the need

Entering needs

Following a field trip (survey of breeders and restaurant managers in the town of Ngaoundéré-Cameroon), we present here some major needs of stakeholders in terms of equipment for preserving meat products:

- No more than 3 hours of transformation time per cycle
- Transform product size ranging from 10 to 2000 per cycle
- The finished product must be tender and not too dry
- Very economical in terms of fuel and energy consumption
- Affordable price/quality ratio
- No exposure to heat and smoke
- Improve product quality (especially broilers)
- No loss of information

Statement of needs

The smokehouse-dryer should allow breeders to preserve chickens for long-term availability and without risk of bacteriological contamination after consumption. Figure 4 is an illustration of stating needs using the horn tool.

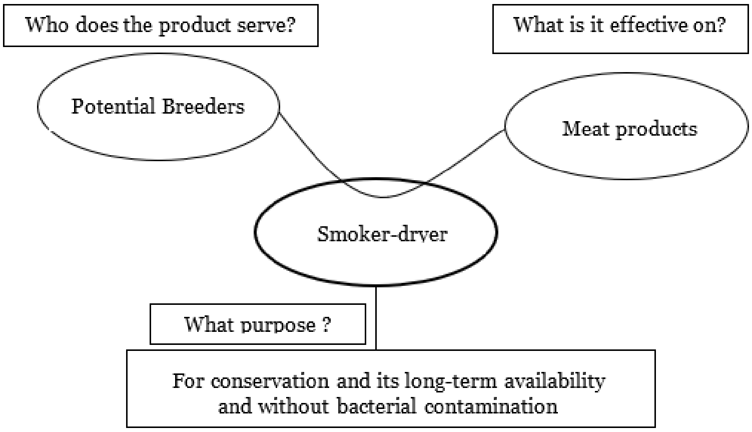

Figure 4. Statement of needs

Validation of needs

- It is for the conservation and availability of chicken while guaranteeing good hygiene that this need exists. This would allow a reduction in poverty in general.
- When farmers can satisfy the current market without keeping the chickens, then the equipment can disappear.
- The increase in the human population leads to the evolution of the product.
- By making the product disappear, we will probably see an increase in the cost of purchasing chicken, its difficulty in obtaining it as well as an increase in poverty.
- By developing it, we can witness the popularization of chicken in our markets like that of fish as well as a considerable reduction in purchasing costs. So, reduction of poverty in the general case.

Feasibility study

Identification of service functions

Figure 5 is an illustration of the relationships that the external elements maintain with each other through the smoker-dryer on the one hand, and the interactions that they carry out with the environment on the other hand using the Octopus diagram tool. The main function that the equipment must fulfill is to be able to extract water efficiently from meat products.

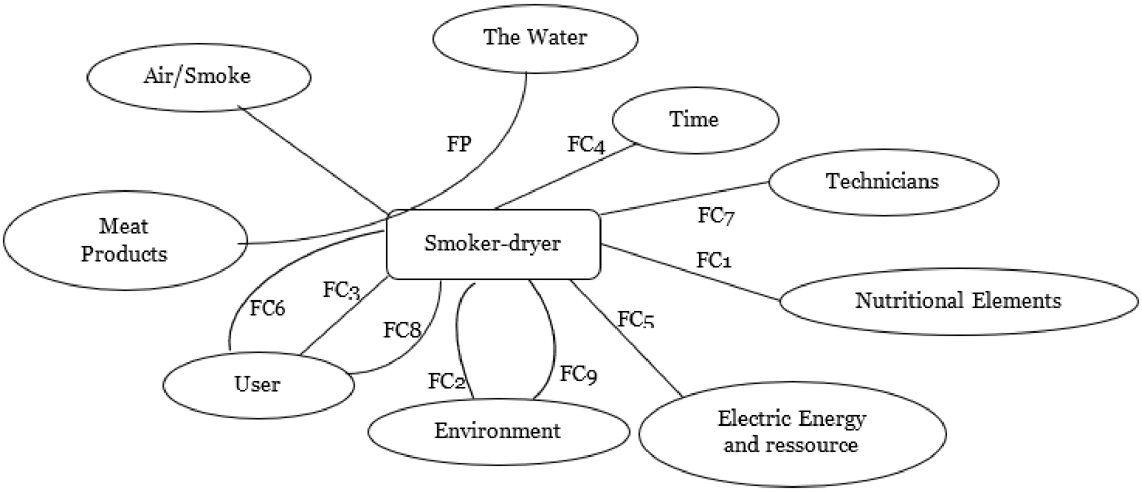

Figure 5. Identification of service functions

Characterization of SF

The equipment must above all fulfill its main function which is to extract water efficiently from meat products, the assessment criteria of which is based on the quantity of water remaining in the meat product which must never exceed 30% of which they can continue to dry naturally in the open air and the extraction speed must not exceed 3 hours. In addition, the finished product leaving the equipment must not have any trace of polycyclic aromatic hydrocarbons (PAH) and must not consume more than 200 watts per hour. Table 2 represents the characterization data of the service functions with their assessment criteria and their level of flexibility.

Table 2. Characterization of service functions

Function	States	Appreciation criteria	Flexibility level
FP	Extract water from meat products	Amount of water remaining	0 to 30%
		Extraction speed	No more than 3 hours per cycle
FC1	Protect the product from bacteria	Number of bacteria present and their quantity	0
		Quantity of dust and ashes	None
		Quantities of PAHs	None
FC2	Retain product nutrients	Percentage of nutrients lost	Less than 5%
FC3	Ergonomic	• Smoke leak • Exposure to fire • User supervision and control	• Negligible • None • Just the initial setup and remote control
		Number of operations to be performed by the user	1
		Protection of users against	Yes

		overheating and electrocution	
FC4	Fast	Duration of a transformation cycle	No more than 3 hours
FC5	Use a small amount of electrical energy and a small amount of sawdust needed	Amount of energy consumed per cycle	No more than 200W per hour
		Sawdust volume for one cycle	5L per cycle
FC6	Configure operating parameters	Difficulty level	Very easy
FC7	Be easy to troubleshoot	Difficulty of disassembly, assembly, identification of circuit blocks	Easy
FC8	Resist the ambient environment	Bearable operating temperature	Up to 450°C
		Resist water	Yes
FC9	Aesthetic	Attractiveness	Average

Prioritization of FS

Table 3 below represents the hierarchy of service functions. From this table, we can clearly identify that the priority function is the main function (FP) followed by the constraint functions FC1, FC2, FC3 and FC5. The least priority functions are the FC9 functions followed by the FC6 and FC8 constraint functions.

Table 3. Identification of service functions

	FC1	**FC2**	**FC3**	**FC4**	**FC5**	**FC6**	**FC7**	**FC8**	**FC9**	**Pts**	**%**
FP	0	1	3	3	3	3	3	3	3	22	22,22
	FC1	1	2	3	3	3	3	3	3	21	21,21
		FC2	2	3	3	3	3	3	3	20	20,2
			FC3	2	1	3	1	1	2	10	10.1
				FC4	0	3	0	0	1	4	4.04
					FC5	3	2	2	3	10	10.1
						FC6	1	0	2	3	3,03
							FC7	2	3	5	5,06
								FC8	3	3	3,03
									FC9	1	1.01
									Total	99	100

Design

Matrix of contradictions

We present in Table 4 the conversion of the service functions into contradiction which we report in the Triz contradiction matrix. In fact, by wanting to improve the temperature in the product to extract the water quickly, we see a loss of substance as well as the deterioration of the quantity of material and/or substance and productivity. The resolution of its contradictions is possible through the application of one or the combination of these principles 3, 17, 15, 21, 28, 29, 30, 31, 35, 36, 39.

Table 4. Matrix of contradictions

	Resistance	Waste of energy	Loss of substance	Waste of time	Quantity of material/substance	Productivity
Strength (Intensity)	35, 10, 14, 27					
Resistance				29, 3, 28, 10		29, 35, 10, 14
Temperature			21, 36, 29, 31		3, 17, 30, 39	15, 28, 35
Energy spent by the moving object						12, 28, 35
Loss of substance	35, 28, 31, 40					
Loss of information		19, 10		24, 26, 28, 32		13, 23, 15
Harmful factors acting on the object			33, 22, 19, 40			22, 35, 13, 24
Productivity						

Search for ideas and solutions

The search for ideas and solutions consists of searching for the optimal solution among the suggestions offered by the principles of inventions retained. In our case, we instead made the combination of several suggestions among which we can list:

- Operate each part of an object in the conditions most appropriate to its operation obtained using principle 3.
- Reverse the actions used to solve a problem obtained from Principle 13.
- Use a multi-story object layout instead of a single story. Use a multi-layer assembly of objects instead of a single layer proposed by Principle 17
- Replace an expensive object with several inexpensive objects, having certain qualities (such as lifespan, for example) of principle 27.

Replace a normal environment with an inert environment following the study and evaluation of the suggestions of principle 39.

3 model of the equipment

Following the search for optimal solutions among the suggestions offered by the 40 principles of inventions, we offer in Figure 6 one of the 3D models designed while integrating the service functions and the requirements of the actors which has been validated for an achievement

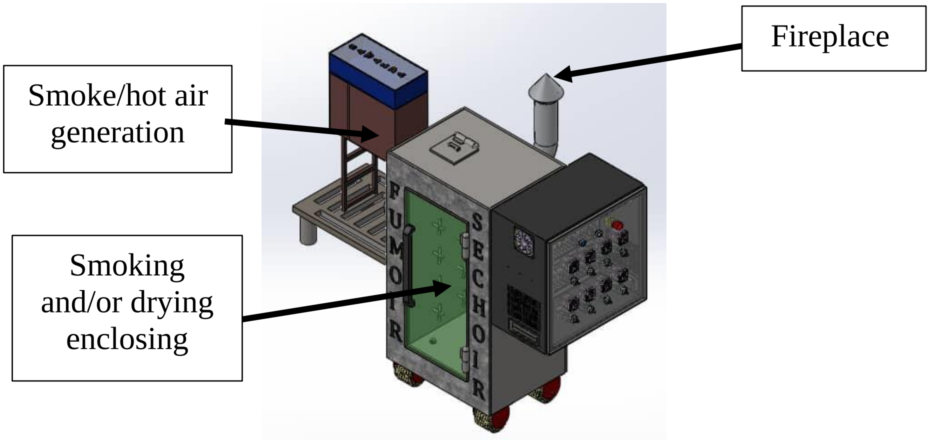

Figure 6. 3D smokehouse-dryer model

Heat flow simulation

Figure 7 is the illustration of the heat flow simulation in the 3D model. We can clearly observe that the heat flow is homogeneous at all points in the smoking/drying chamber.

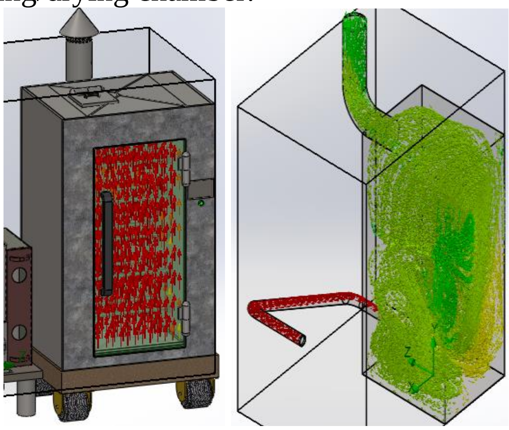

Figure 7. Simulation of heat flow in the 3D model

Conclusion

Having reached the end of our work, it should be remembered that we analyzed the needs and we proposed a 3D model of the equipment. In doing so, we first, in this document, captured and stated the needs of chicken breeders and restaurant managers in the city of Ngaoundéré-Cameroon which were subsequently validated. Then we identified the service functions which were characterized and prioritized. The characterization and prioritization allowed us to seek ideas and solutions for the design of equipment integrating the customer needs previously entered. From this study, it appears that it is possible to integrate the needs of stakeholders from the design and construction phase using the Triz method. The realization and experiments should be carried out with the aim of verifying whether all requirements will also be taken into account in this phase.

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Conflicts of Interests: The authors reported no conflict of interest.

Data availability: All data are included in the content of the paper.

Ethical declaration

This study has been approved by PEPITA-UN (Projet d'Excellence en production d'Innovations Technologiques en Agro-Industrie de l'Université de Ngaoundéré) and the principles of the Helsinki Declaration were followed.

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