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DEVELOPMENT OF LIVESTOCK PRODUCTS FROM RECYCLING OF INDUSTRIAL WASTE AND VEGETBLE FIBERS

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ABSTRACT

The present paper discusses the development and project of three livestock products and their respective manufacturing processes – they are composed by vegeto-polymeric compounds acquired from plastic films and vegetable fibers. This study mentions a technological innovative project from the Brazilian National Council for Scientific and Technological Development – Program for Human Resources Education in Strategic Areas (CNPq-RHAE, in Portuguese). The activities of research were performed in a partnership between two Brazilian federal universities and a manufacturer of flexible plastic packaging, and enabled the construction of a plan to implement a new business unit. In the end, the new manufacturing unit is aligned to the Brazilian National Policy for Solid Waste (Federal Law #12.305/2010), which permits to aggregate value to industrial waste to produce new livestock products.

Keywords: Industrial plastic waste; vegeto-polymetic compounds; development of livestock products.

1. INTRODUCTION

the present model used in interfirm competition preconizes a paradigm of a nimble availability of products (goods and/or/services) and a higher speed of worldwide consumption, which has natural consequences, such as the elevated consumption levels of material and energetic supplies. Schumpeter *et* McDaniel (2009) consider that corporations that aim to increase financial results must develop goods and processes which are technologically advanced in order to achieve comparative advantages in costs, quality, and delivery, thus permitting those companies to acquire a larger margin of profit from market prices, and depending on the elasticity of the demand, combine those aspects with the lower price and higher margin of profit in comparison with the direct rivals, in order to have a larger participation in the market, in profitability, and in the defense of competitive positions.

In this sense, PNUMA (2011) presented a report for the United Nations (UN) with forecasts that show a three times higher growth of the consumption of natural resources until 2050, which suggest a collapse in the provision of raw materials and energy to processing industries. As a conclusion, the present economic model is not sustainable in a long run, once the consumption of natural resources grows up faster than the production of raw materials and production inputs. Then it is necessary a smart use of the resources to avoid unnecessary waste and to focus on reuse/reinsertion of byproducts, processes waste, and post-consumption materials into the productive chain.

The post-usage of industrial waste is being the interest of several applied studies, which does not only call attention from its environmental side, but also from its socio-economic aspect, once it enables to aggregate value to these materials through the development of new products conceived from the idea of business sustainability. According to Paixão, Roma and Moura (2011), the present Brazilian production of industrial solid waste is estimated in one hundred million tons, but the appropriated environmental treatment of this waste is one of the elements of the Brazilian National Policy

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for Solid Waste (Federal Law #12.305/2010), which the main points are:

The adoption of sustainable production standards and final destination environmentally adequate to the waste produced in the productive processes and industrial plants, through routines of reuse, recycling and recuperation;

The development of environmental and organizational management systems to improve productive processes and reuse of waste inside the original production and/or redirected to other productive chains;

The incentive to scientific-technological research and technical-financial cooperation between public and private sectors to develop new and clean goods, processes, and technologies to minimize environmental impacts;

Stimulus to the development, manufacture, and availability to the market of products originated from reused materials.

The intense interfirm competition, characterized by sudden technological changes, goods that have considerably short life cycles, and consumers/users that are more and more demanding, forces corporations to develop/design goods with innovative technological contents made available under average market prices, without significant unit contribution margins (Clark *et* Wheelwright, 1993). Thus, manufactured products with reused materials from innovative technologies can increase financial profit of productive corporations, avoiding the expenses in complex external reprocessing, and environmentally safe discharge.

For the OECD (2005), the innovative activities linked to development and technological advancement of goods and processes must be integrated to the competitive strategies of manufactory organizations. More than two decades ago, Clark *et* Wheelwright (1993) already demonstrated the intense industrial competition due to the constant changes in expectations/necessities of clients and the accelerated evolution of technologies, materials, and processes, making them the driving force that pushes the development of products (goods and/or services) in a fast pace and directed to segmented consumer markets. Cheng (2000) highlights that the development of products originates from a permanent alignment between necessities/demands from final clients, business opportunities, technological possibilities, and central competences of the corporation from a horizon of planning that permits the survival and corporate development.

The rational use of recycled materials follows the philosophy of productive sustainability (socioeconomic, environmental, and energetic), which is now viable through processes of cleaner production (P+L). The sustainable development, according to Rossini *et al*. (2008), is attached to the use of technologies in the processes and products that enable the creation of socioeconomic, environmental, and technological strategies combined, aiming to optimize the use of raw materials, water, and electricity.

The main objective of this article was to perform innovative roles to the development/project of three products destined to the creation and management of cattle (equipment for cattle feeding equipment and diet supplement), as well as to line up the macroprocess of a manufacturing system of continuous profilved of vegeto-polymers (a combination of plastic industrial waste and vegetable fibers from sugar--alcohol industries), that must be used in the processing of the mentioned products. The triad "compound materials – livestock products – sustainable productive system" gave the support to implement a new factory unit annex to the industry of plastic flexible packaging, located in the Great Dourados region, in the Brazilian state of Mato Grosso do Sul.

The development/project of livestock products and its respective manufacturing processes is based fundamentally in the aggregation of value to industrial plastic waste and reinforcement vegetable fibers from sugar-alcohol regional activities, permitting the generation of work and income to local population. For the Brazilian Ministry of Science, Technology, and Innovation (MCTI, 2012), the sustainable production depends on a constant improvement of products and processes based on the conceptual for a cleaner production and for an organization of recycling chains, in consonant to the Brazilian National Policy for Solid Waste, in which the sustainable regional development must be supported by competences and resources that are available locally.

In this sense, Smith *et* Ball (2012) point out that a sustainable productive organization is the one that searches to make its business processes economically viable, environmentally safe, and also promoting social well-being. In this sense, strategies, action plans, and decisions must contemplate the fulfillment of the "sustainable competitive tripod" (economic, social, and environmental). Dues, Tan and Lim (2011) mention that industrial projects aimed to sustainability are characterized by the incorporation of concepts and methodologies that refer to social responsibility, better practices in corporate governance, ecoefficacy, analysis of the life cycle of products and processes, programs of "zero emission", certified environmental management, and cleaner production.

In the end, crescent demands in the agribusiness chain for new products, processes, and services can motivate other productive segments of raw materials/inputs, consumer/capital goods, and suppliers of highly aggregated technological services, motivating the diversification of the productive support strata in Brazil, and a consequent improvement of

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the conditions to a productive and sustainable inclusion for new enterprises.

2. REVIEW OF LITERATURE

2.1. Product development process

The Product Development Process (PDP) represents the set of activities that lead to the creation of a new and/or modified line of products, sent to the market through time, including the generation of opportunities, selection, and transformation of these goods and/or services, which will become available to the final consumer (Loch *et* Kavadias, 2008). Rozenfeld *et al.* (2006) and Krishnan *et* Ulrich (2001) defend the idea that PDP is initiated by the identification of cline requests, evaluation of competitive/functional strategies, and the analysis of technological possibilities, restrictions, and necessary resources to the development and project phases.

For Ulrich *et* Eppinger (2011), the development of a product includes activities that started form the view of a market opportunity, production, sales, and distribution of a certain product. Wang, Gou and Liu (2012) define market opportunities as situations in which new goods, services, raw materials, and organizational methods are introduced and sold by prices that are substantially higher than the production costs, as the discovery and exploitation of opportunities can be interpreted as innovative activities and entrepreneurship – and as a consequence, new tangible goods and services are considered as a 'physical representation of market opportunities'.

The complexity in creating new products was observed by Baxter (2011), who affirms that it is an activity that requires researches, careful planning, meticulous control, and systematic methods. The division of the product development process must be performed from the configuration od a model based on interdependent steps, jutting the relevance of planning and quality control of PDP – under this scope, the intrinsic content of each stage can be adapted according to the nature of the product and the productive organization setup.

In this sense, Back *et al*. (2008), Chen *et al.* (2008) and Akgun, Lynn and Yilmaz (2005) dissertate regarding the eminent strategic content of the product development process from the use of innovative learning processes and knowledge management methods necessary to perform complex organizational actions, intended to acquire technological, aesthetical, and/or functional differentiation in products or even in the repositioning of already marketed ones. In the end, PDP also can be considered as a managerial, strategic-rational, and methodological process to establish a set of innovative actions to be performed, in rigid schedules, responsible and committed teams, and using technologies and financial support.

2.2. Clark and Wheelwright's methodology for product development

The classical 'Strategic Structure for the Development of Products', proposed by Clark *et* Wheelwright (1993) has five stages: (1) development of conception (definition of opportunities and targeted market, technical possibilities, product architecture, and final conception); (2) product planning (detailed market study, investments, schedules, necessary resources, specifications, and construction of models); (3) project for product and process (detailed project of the product and productive system, prototyping/tests and development of providers); (4) pilot production and ramp-up (evaluation/tests of process and material supply, clearance for regular production, and insertion of the product in the market); (5) introduction of the product in the market (elevation of production levels, filling distributing channels, and stabilization of the process). The general scheme of the methodology for the product creation of Clark *et* Wheelwright (1993) is seen on Image 1.

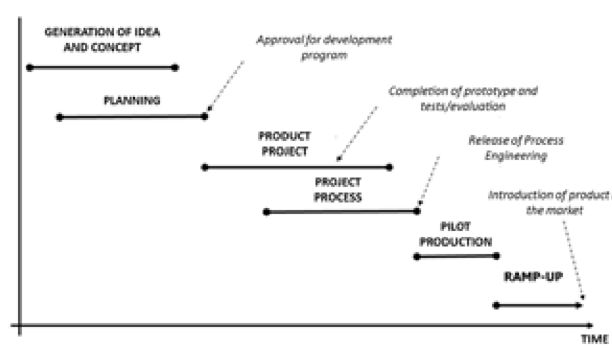

Image 1. Strategic structure for product development.
Source: Clark *et* Wheelwright (1993).

According to Image 1, product development is divided in different stages that may or may not occur simultaneously, depending on how the operational setup will impact in cost reduction, use of resources, and/or involved lead times. Thus, there is a strong interdependence in each product development stage, as the result of one stage is considered the support moment to the performance of the subsequent stage – and for this reason, the decisions taken in each stage are reflected in the development of the product as a whole.

The first two stages of the methodology refer to the development of the concept and the planning of the product, in which data prospects/information regarding market opportunities, competitiveness, technical viability, and product re-

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quisites must be combined in the architecture of it, including conceptual project, targeted audiences, desired performance level, investments, and economic-financial impacts. Hence, there is a preoccupation with the sharing of key elements already developed in previous projects, in order to create 'differentiated solutions' for the new products, with viable resources to creation and production.

Ulrich *et* Eppinger (2011) pointed out that data/information collection, later identification and classification of consumer necessities as important ways to achieve primary particularities of the product. Once identified the needs from the targeted audience, they must be translated into specifications to be used in the conceptualization of the product, which initially represents an approximate description of the technologies used, operating principles, architecture, and form/aesthetics. Based on the views of Ullman (2009), the concepts are controlled abstractions of the product, which can be presented as diagrams, sketches, simple models, calculations, and/or descriptive texts.

From the selected concept, the following step must be de definition which are the components of the product, and what are the roles of each one – this stage is considered a key-stage in product development, as in this moment the decisions will be taken in relation to final operation and architecture of the product (Otto *et* Wood, 2001). Lee *et* Wong (2011) mentioned that the construction of technical systems and the final configuration of the product are acquired after the performance of low-scale tests of the proposed concepts (modeling and evaluation), as well there is the possibility to perform additional assessments for possible clients, culminating with the approval of the product development program, integrating three crucial edges of PDP: marketing, technology, and organization.

The following stage deals with the integration between Product Engineering and the Process one, which approaches the development/detailed project of the product, construction/prototyping testing, operational production and assembling project, required tools and equipment for production in commercially viable scale. An aspect with great relevance is the combined cycle 'project-build-test' for a product/process (physical, computer-generated, and prototype models) – in the case real and/or virtual models do no respond to the required specifications and the desired performance levels, there will be changes, and this cycle is repeated until the proposed specifications are reached for the product in question.

Inside PDP logics, the full/integrated specification of the product and its productive process is understood as an important question to achieve a successful sales result. In this sense, Müller *et* Fairlie-Clarke (2003) propose a self-evaluation method for new products and process as means to improve the success rate during the introduction to market stage, in which is identified the necessity of a non-prescriptive proceeding to evaluate the development process of the existing or proposed product in a more detailed level, analyzing in the context of the practices in world excellency, the products, the processes, the proceedings, and the reached markets.

Hence, the project of manufacturing and assembling operations, aligned to the development of suppliers, can be considered the stage in which all possible ways to generate a product under the lowest cost available are studied, without forgetting to prioritize quality. Ullman (2009) considers that the biggest challenge in this moment is to choose the best process to the manufacturing of the product, having in mind that for any component there are many other possibilities for operation and consistent productive scripts.

Therefore, the making of a product that respects market specifications and performance technical conditions indicates the beginning of the following stage, of the production of the pilot-batch, under the presumption that systems, subsystems, and developed/projected (and previously tested) components will be normally produced and internally evaluated, in order to validate the new and/or modified process. The final stage of the methodology of product development of Clark *et* Wheelwright (1993) is called ramp-up, indicating the beginning of the commercial output for the product, which can start with a reduced volume – a gradual growth of the production is set by scaled increases based on the reliability of the process, suppliers, and product distributors (wholesalers and retailers).

3. RESEARCH MATERIAL AND METHOD

3.1. Corporation description

INFLEX Indústria e Comércio de Embalagens Ltda. (INFLEX Packaging Industry and Commerce LL.), is located in the Great Dourados, a municipality of the Brazilian state of Mato Grosso do Sul, has ISO 9001:2008 and P+L Waste Management certificates, 200 employees and a manufacturing plant of 7,200 m^2 (total area of 35,000 m^2). The company produces 400 tons/month of flexible plastic packaging, mono- or multi-laminated, printed in flexographic process using gear less technology, liners to produce duple face tapes and stand-up and zip plastic bags, from extruded films of High & Low Density Polyethylene (HDPE and LDPE), Polyethylene Terephthalate (PET), Bi-Oriented Polypropylene and Polypropylene Twist (BOPP and PPT), Bi-Oriented Polyamide (BOPA), and other metalized films. The products are destined to regional agro-industrial complexes and other industries located all over Brazil.

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The job shop production gives priority to firm order backlog, and the inclusion of orders according to the availability of productive capacity, working with daily/weekly assembling orders, and a firm schedule for fifteen days, and a monthly plan horizon produced by the apps Microsiga Protheus 11, from Totvs, and Preactor 400APS, from Preactor International.

The manufacturing system is of an intermittent type, based on batches and functional physical setup (in departments). The productive process englobes layout development, and technical project of the product based on client's request, creating printing plates (external providers) and packaging production, which include the extrusion/co-extrusion operations of up to three layers of plastic films, flexographic impression, simple and/or double lamination, refiling of continuous packaging coils, cutting/welding of individual packages (plastic bags), and shipment/follow-up. The refiling operation is the one responsible for an average creation of 30 tons/month of plastic chips (which are 85% of industrial waste), considered regular waste amount generated from productive operations.

3.2. Adopted methodology and proceedings

The methodological structure of the study follows the logic of an applied/exploratory research, which Gil (2008), Barros *et* Lehfeld (2007), see as having the premise to build knowledge form the results associated to pragmatic solution to a specific issue, from concepts found in literature. The main objective of bibliographical research is amplifying and dominating an available knowledge, in order to support later researchers to structure their hypothesis and building their models (Lakatos *et* Marconi, 2010). The referred research is also based in the elaboration of a case study, however Yin (2010) highlights that it has an empiric nature and a need to adequate to investigate real problems, especially when the issues to be observed are not clearly defined.

The present study was originated from the execution of a research project CNPq-RHAE, being possible through technological-scientific cooperation between INFLEX Corporation, the Universidade Federal da Grande Dourados (UFGD; Great Dourados Federal University, in English) and the Universidade Federal de São Carlos (UFSCar; São Carlos Federal University, in English). The proceedings used in the study were based on the performance of the following sequential and interdependent steps:

- Building a theoretical reference regarding product development and project;
- Performing technical visits to rural proprieties to study and support the details and conditions to apply the proposed products;
- Adapting the development methodology of the product, according to Clark *et* Wheelwright;
- Detailed development/project of three livestock products (equipment) destined to feeding and supplementing cattle – stationary trough with cover; mobile trough-sled without cover, and automatic equipment to supply mineral salt.
- Performing a macroprocessual plan, listing machinery/equipment and factory plan to line up sustainable productive system.

As discussed previously, the development/project of the proposed products was based in an adapted model from Clark *et* Wheelwright's (1993) methodology, which is composed by the following stages and associated activities: (1) Conceptualization and development of Regional Agricultural and Livestock Products, which include the design of the architecture (systems, subsystems, and components), and the performance of technical studies to propose the final concepts of products; (2) Product and Process Integrated Project, which deals with the technical detailing of products, bi-dimensional and tri-dimensional drawings, list of materials, and lining up the sustainable production system.

4. RESULTS FOUND

4.1. Products

In a preliminary stage, the requisites of the three products were based on general normative recommendations from agricultural research centers and universities. The constructive materials used are flat rectilinear profiled of vegeto-polymeric compound material (width varying from 100 to 500 mm, and thickness varying from 15 to 30 mm), solid profiled in rectangular sections (width varying from 50 to 120 mm, and thickness varying from 50 to 60 mm) and solid profiled in square section (with transversal sections varying from 50 to 200 mm), processed in twin screw extruder with volumetric dispensers separated to be fed by polymeric blends and micronized vegetable fibers, vacuum degassing, and cooling by water bath; cutting and separating of extruded material in specific equipment in the front line (rotating saws, pneumatic positioners and collectors).

The extrusion process of thermoplastic products present relative lower costs when comparing to injection and thermoforming, an elevated flexibility in making products with consistent and varied transversal section, besides the possibility of reutilization of material leftover, which are normally discarded through other processes of thermoplastic conformation (Manrich, 2005).

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According to Rodrigues Filho *et* Azevedo (2005), the stationary trough with cover to feed cattle can be also destined to accommodate mineral salt, being built preferably with non-corrosive materials and fixating elements made by a stainless source, as well as having a cover to protect is form the rain, sunstroke, and evening humidity. Therefore, the project was performed based on technical materials suggested by Homma (2006), Rodrigues Filho *et* Azevedo (2005), and Souza, Tinoco and Sartor (2003). Image 2 demonstrates the final concept, designs, and dimensions for the stationary trough with cover.

According to Embrapa (1999), the trough-sled without cover is used for large size feeding (*in natura* or crushed vegetables), and it was improved by Embrapa Pecuária Sudeste de São Carlos/SP. It is easier to move around and a longer lifespan when comparing to troughs made out of wood. The construction is done with planks set on two joists that works as skis – the trough-sleds are used in the feeding of animals due to their mobility (displacement by tractor or draft animal), resistance (reinforced structure), and durability (lower part does not touch the ground). The development/project is based on the technical material designed by Embrapa (1999). Image 3 demonstrates the final concept, designs, and dimensions for the trough-sled without cover.

Based on Nunes (1998), the automatic equipment to supply mineral salt can also be used in food supplementation of beef and/or dairy cattle. In comparison to conventional open saltshaker, this equipment enables a significant reduction of losses due to more protection against environmental elements against mineral salt, vitamin-mineral supplements, and/or stored feed – the access to the content is done through a tilting door that is opened by the animals.

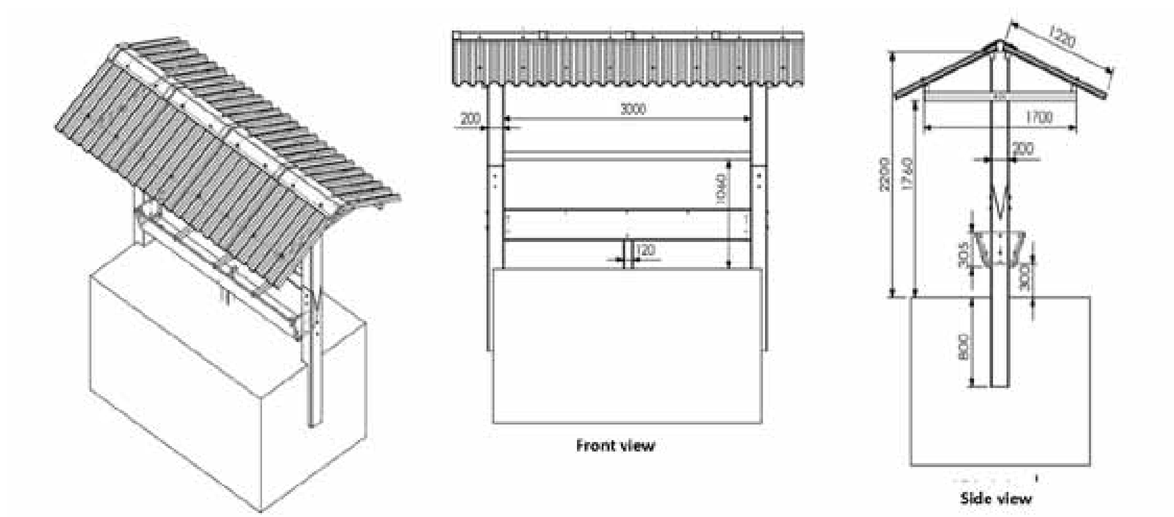

Image 2 - Concept, design, and dimensions – Stationary trough with cover.
Source: The authors themselves.

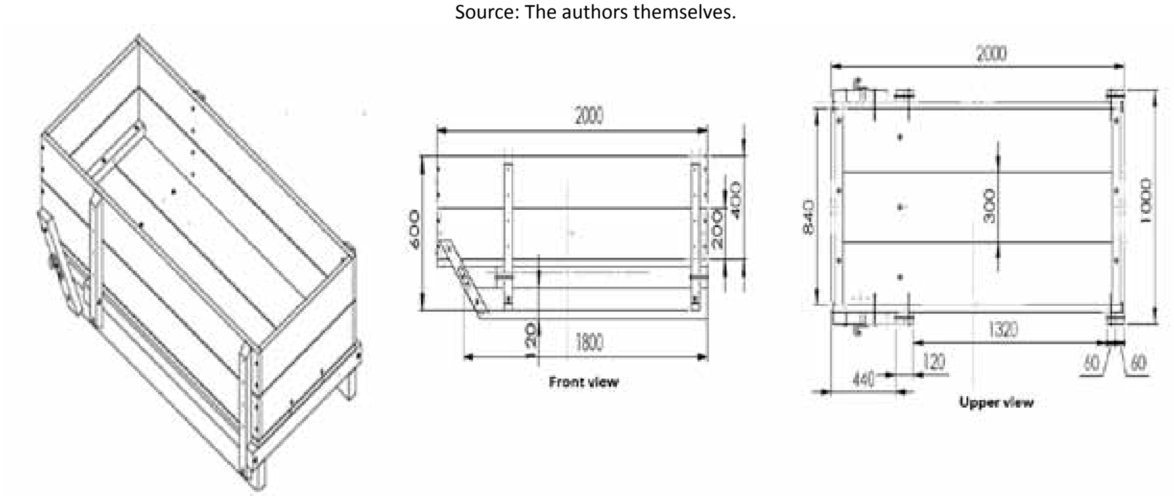

Image 3. Concept, designs, and dimensions – Trough-sled without cover.
Source: The authors themselves.

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The product was dimensioned as described in the technical publications from Embrapa Centro-Oeste, specially the one written by Nunes (1998), with the substitution of the suggested fixing elements. Image 4 shows the final concept, designs, and dimensions for the automatic equipment to supply mineral salt.

Image 5 demonstrates the material lists for the three products created.

4.2. Macroprocess plan and manufacturing plan

The sustainable production system has nine interdependent sub-processes and their corresponding operations. This productive system is composed by the macroprocess plan, list of machinery/equipment, and productive flowcharts. Image 6 demonstrates the flowchart for the complete productive process.

Based on Image 6, the nine sub-processes (macroprocess) were decomposed according to their own operations. Then, the sub-process "baling plastic chips" is composed by four operations: (1) arrival of industrial waste – the residual plastic chips from INFLEX are placed in wire fenced containers and transported to the new factory plant; (2) separation/classification of chips according to the composition of the residual plastic films; (3) baling the selected chips (compression and strapping in vertical squeezers); (4) accommodation of bales in metal pallets, moving/storing in metal shelves.

As a complement, the sub-process "processing vegetable fibers" is composed by four operations: (1) receiving baled vegetable fibers (compressed, strapped, and in pallets) from providers (from sugar-alcohol industrial plants), weighing and unloading trucks, and moving the load; (2) drying and milling the *in natura* fibers in flash dryer (continuous system), fed by Liquefied Petroleum Gas (LPG) and in windmills with rotary hammers; (3) particle classification of vegetable fibers through rotary sifters; (4) accommodation of processed particles in plastic drums, placement of drums in pallets, and moving/storing in metal shelves.

The sub-process of "plastic chip granulation" is divided in four sequential operations: (1) grinding/crushing of plastic chips in granulator mills of rotary blades, and pre-classificatory sieving; (2) extrusion and polymeric granulation (making of pellets); (3) placing pellets in plastic drums; (4) disposing drums in pallets, and moving/storing in metal shelves. Next, the sub-process "preparation and homogenization of polymeric blends" is composed by two operations: (1) preparation of polymeric blends by electronic weighing and homogenization in mixers of rotary drums; (2) placing the prepared/homogeneous blends in tilting metal buckets.

The sub-process "extrusion of composites, conformation, and cutting profiles" is done in five operations: (1) moving tilting buckets of homogeneous blends and the pallets of drums filled with particulate vegetable fibers to the extrusion section for composition, conformation, and cutting extruded profiles; (2) extrusion in double screw of the vegeto-polymeric composites (agglutination of blends and particles of vegetal fibers); (3) formation of profiles by double screw extrusion; (4) cutting of profiles with automated dis saws; (5) storing cut profiles in cantilever shelves.

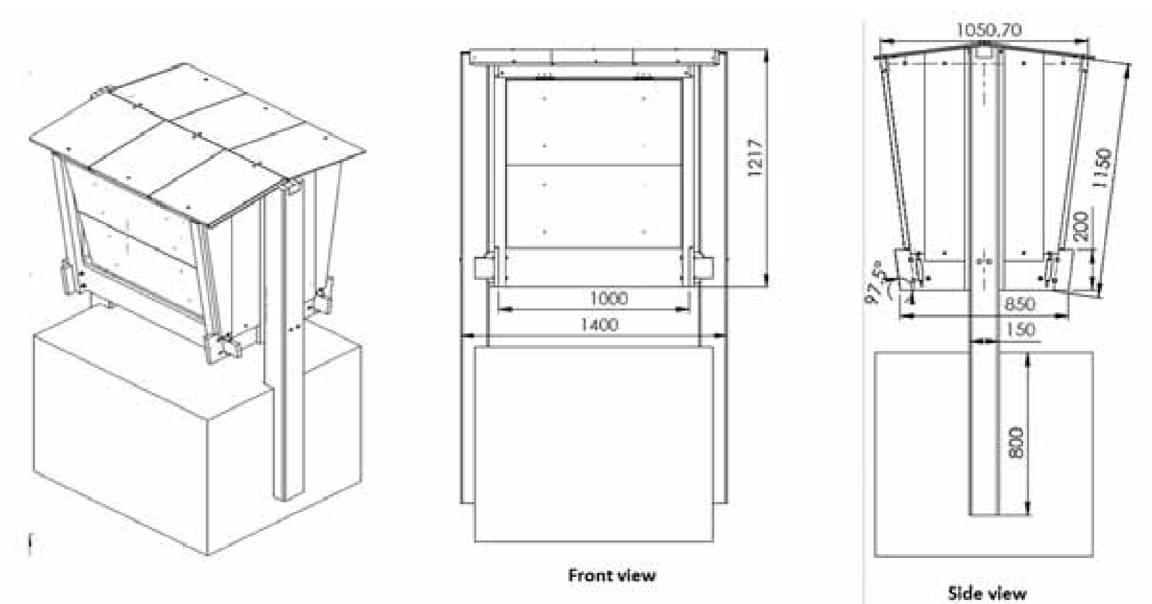

Image 4 - Concepts, designs, and dimensions – Automatic equipment to supply mineral salt.

Source: The authors themselves.

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(a)

Item #	Name of the part	Dimensions (mm)	Quantity
1	Lateral column	200 X 200 X 1500	4
3	Central column	100 X 100 X 1000	1
4	Roof beam	60 X 80 X 1700	2
5	Rafter roof	50 X 60 X 4200	4
7	Fiber cement tile	8 X 1100 X 1220	8
9	Fiber cement ridge	5 X 1100 X 400	4
14	Trough side plate	30 X 300 X 500	2
15	Trough lower dish	50 X 50 X 340	3
16	Trough internal support	50 X 50 X 240	4
18	Trough longitudinal plate	25 X 30 X 3000	3
19	Trough upper dish	50 X 50 X 500	3
22	Trough intermediate beam	60 X 80 X 3050	1
23	French screw	3/8" X 11"	4
24	French screw	3/8" X 9 1/2"	4
25	French screw	3/8" X 9"	4
26	Normal hex nut	3/8"	12
27	Flat washer	3/4"	12
28	Hex nut self-tapping screw	5/16" X 2.3/4"	20
29	Self tapping screw with pan head screwdriver	5.5 X 50	20
30	Screw set for fiber cement roof with sealing washer	5/16" X 5.9	32

(b)

Item #	Name of the part	Dimensions (mm)	Quantity
1	Longitudinal support	60 X 120 X 1800	2
2	Side support	50 X 60 X 600	4
3	Bottom support	50 X 50 X 840	2
4	Lower dish	60 X 80 X 1000	2
5	Closing plates - bottom part	30 X 300 X 2000	3
6	Closing plates	30 X 200 X 2000	2
7	Closing plates - lower part	30 X 200 X 2000	2
8	Side plate - lower part	30 X 200 X 840	2
9	Side plate - upper part	30 X 200 X 840	2
10	Hook support	50 X 60 X 400	2
11	Hex nut self-tapping screw (stainless steel)	5/16" X 2.3/4"	18
12	French screw	3/8" X 5"	10
13	Flat washer	3/4"	10
14	Hex nut	3/8"	10
15	Hook		2
16	Self tapping screw with pan head screwdriver(stainless steel)	5.5 X 45	32
17	Self tapping screw with pan head screwdriver	6.3 X 50	4

(c)

Item #	Name of the part	Dimensions (mm)	Quantity
2	Column	150 X 150 X 2295	2
3	Longitudinal support	50 X 60 X 1152.5	2
4	Transversal longitudinal support	50 X 60 X 1000	2
5	Closing plate - left side	25 X 200 X 973	2
6	Closing plate - right side	25 X 200 X 973	2
7	Closing plate - central	25 X 200 X 1200	2
8	Closing plate - sublateral	25 X 200 X 1040	4
9	Roof support	60 X 80 X 1400	1
11	Dividing plank	30 X 300 X 1000	1
12	Door plank	15 X 450 X 920	4
13	Door support	20 X 100 X 900	4
17	Wedge	10 X 43 X 160	4
18	Side plank	25 X 200 X 850	2
19	Front plank	25 X 200 X 1250	2
20	Roof plank	15 X 450 X 560	6
21	Floor plank	30 X 300 X 1000	2
22	Floor support		2
23	Upstream left support	50 X 50 X 1150	2
24	Upstream right support	50 X 50 X 1150	2
25	Hex nut self-tapping screw	5/16" X 70	14
26	Self tapping screw with pan head screwdriver	4.2 X 32	16
27	Self tapping screw with pan head screwdriver	5.5 X 50	36
28	Wood screw simple screwdriver	4.8 X 22	24
29	Wood screw simple screwdriver	4.5 X 45	4
30	Flat washer	3/4"	16

Image 5. Materials lists – (a) Stationary trough with cover; (b) Trough-sled without cover; (c) Automatic equipment to supply mineral salt.

Source: The authors themselves.

The sub-process "preparation of extruded profiles (measuring, cutting/fitting, and drilling)" has three inter-related operations: (1) measuring/establishing points of cutting, fitting, and drilling in the previously cut profiles; (2) performance of cuts, fits, indentings, and drills on the cut profiles, which then are renamed as prepared cut profiles; (3) moving and storing the prepared cut profiles in cantilever shelves.

The sub-process "painting prepared cut profiles" is performed in two operations: (1) painting the prepared profiles by spraying with a compressed air system under segregated environment (gas exhaustion and mist system); (2) moving and storing the painted profiles in the packaging section for finished products. Then, the sub-process "preparing product assembling kits" is composed by three linked operations: (1) receiving fixation elements (screws, nuts, and washers) acquired from providers, which include activities such checking invoices and documents, counting/weighing, quality control, and sending document for paying; (2) selecting and storing fixing elements in shelves in the warehouse; (3) preparing and storing assembling kits in available shelves of the warehouse.

In the end, the sub-process "packaging finished products" is made by three operations: (1) packaging of finished products, which is done by the activities of strapping to bind prepared cut profiles and/or painted profiles, wrapping with thermo-retractile plastic films to protect and set the strapped profiles/assembling kits in reinforced pasteboard (finished products); (2) moving/storing finished products in the warehouse; (3) final expedition.

Chart 1 contemplates the list of machinery/equipment referred to the sustainable production system here proposed.

With the definition of the sustainable productive system, the project of the initial factory plant has started, which was done using AutoCAD® app, by Autodesk Inc. Based on this initial plant, the placement and re-adequacy of the needed physical spaces was done, considering the work centers required (by the sub-processes and their respective productive operations), warehouse, deposit for finished products and expedition, as well as the delimitation of intermediary stocking areas and internal halls for moving raw material,

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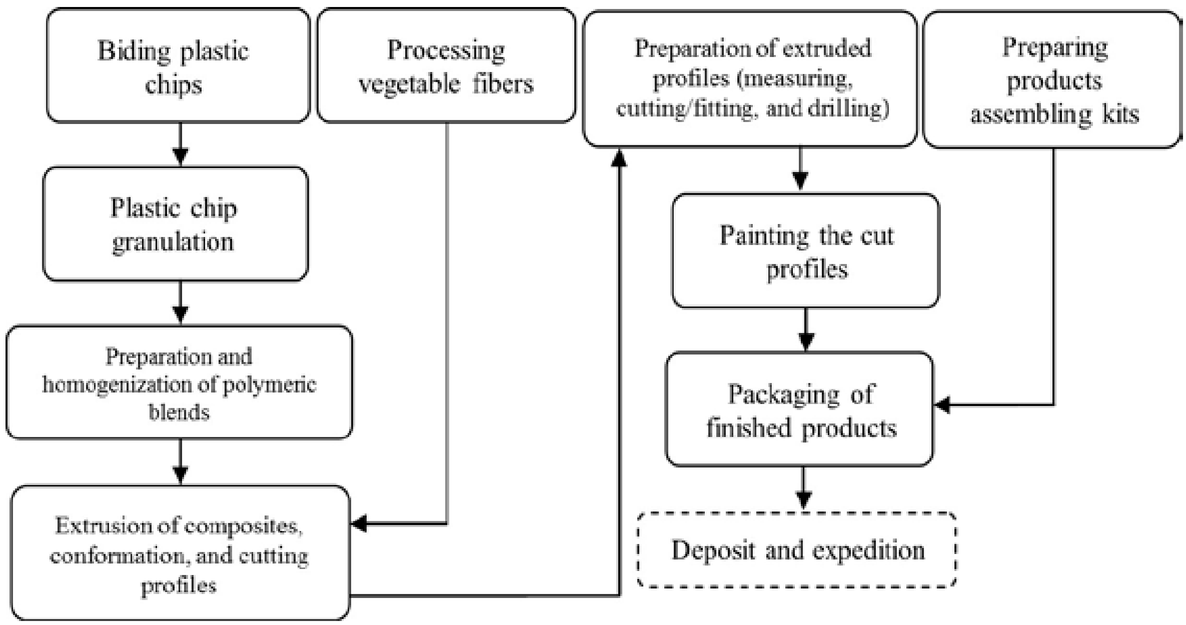

Image 6. Flowchart of the sustainable production system (macroprocess).
Source: The authors themselves.

in-process material, and finished products, thus having the initial physical setup.

On the next step, the design of moving systems and material stocking was performed, based on the use of fork-lifts, pallet trucks, containers, plastic drums, tilting metallic buckets, pallet shelves, and cantilever shelves. After the changes in the factory plant and physical organization, the final factory plant was produced, together with the functional physical setup (Image 7).

In the end, a process map was designed to evaluate the various fluxes of materials present in the productive system, from receiving the raw material/inputs, to the final expedition of the finished products (Image 8).

4.3. Discussion of results

The three products designed to be used to feed and supplement the diet of cattle have important advantages in comparison to traditional products made out of reforested wood (such as pine and eucalyptus), such as:

- Resistance to weather and mechanic shocks (higher durability from the compound materials and reliability of operation);
- Improved characteristics in ergonomics, design, and maintenance (porosity, roughness and superficial finishing superior to common wood products);
- Adequacy to technical specifications from the Brazilian Agricultural Research Company (Embrapa) and correlated institutions;
- Standardized dimensions/tolerances (conformity of the final product);
- Industrial reuse of recycled materials, enabling cleaner production techniques;
- Potential recyclability of livestock products at the end of a life cycle, enabling the reuse of composite materials expended in the manufacturing of new products, due specially to the polymeric matrix used (rich in polyethylene and polypropylene);
- Contribution to sustainable regional development based on agribusiness – agricultural and livestock production, and agricultural industry.

The plant layout developed is based in the functional setup (by process), and the processing of material must be done through the composition of moving standard-sized batches in periodic productive fluxes, and relatively uniform sets of distances covered and production speed. The projected factory plant is composed by two productive areas interconnected, being the first filled with the sectors “baling plastic clips” and “processing vegetable fibers”, which are considered the sub-processes that reuse plastic waste and vegetable raw material. Then, the second productive area

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Chart 1. List of machinery/equipment for the sub-processes and their respective operations.

Sub-process	Operation	Machinery/Equipment	Quantity
Biling plastic chips	Operation 1	Fork-lift fuelled by LPG (1)	1
	Operation 3	Vertical baler	3
	Operation 4	Fork-lift fuelled by LPG (1)	-
Processing vegetable fibers	Operation 1	Fork-lift fuelled by LPG (2)	1
	Operation 2	Continuous flash dryer	1
		Manual pallet truck	1
		Hammer crusher and grinder	3
	Operation 3	Rotary sieve	2
	Operation 5	Fork-lift fuelled by LPG (2)	-
Plastic chip granulation	Operation 1	Fork-lift fuelled by LPG (1)	-
	Operation 2	Granulator mill with blades and hammers	1
	Operation 3	Extruder reclaimer	1
	Operation 5	Manual pallet truck and fork lift fuelled by LPG (1)	-
Preparation and homogenization of polymeric blends	Operation 1	Fork-lift fuelled by LPG (3)	-
	Operation 2	Pallet electronic scale	2
		Horizontal mixer	2
	Operation 3	Fork-lift fuelled by LPG (3)	-
Extrusion of composites, conformation, and cutting profiles	Operation 1	Manual pallet truck and fork lift fuelled by LPG (3)	
	Operation 2	Twin screw extruder (profiles)	2
	Operation 3		
	Operation 4	Automated rotary disc saw	2
Preparation of extruded profiles	Operation 1	Manual pallet truck and fork lift fuelled by LPG (4)	1
	Operation 3	Circular stand saw	2
		Metal tape saw	2
		Horizontal drill	2
	Operation 4	Fork-lift fuelled by LPG (4)	-
	Operation 5	Manual pallet truck and fork lift fuelled by LPG (4)	-
Painting cut/prepared profiles	Operation 1	Painting room with exhaustion	1
	Operation 2	Fork-lift fuelled by LPG (4)	-
Preparation of product assembling kits	Operation 1	Manual pallet truck	1
	Operation 3		
Packaging of finished products	Operation 1	Manual pallet truck	1
	Operation 3	Fork-lift fuelled by LPG (4)	-
	Operation 4	Fork-lift fuelled by LPG (4)	-

Source: The authors themselves.

(1) Used in the sub-processes “baling plastic chips” and “plastic chip granulation”.

(2) Used in the sub-process “processing vegetable fibers”.

(3) Used in the sub-processes “preparation/homogenization of polymeric blends” and “extrusion of composites, conformation, and cutting profiles”.

(4) Fork-lift used in the sub-processes “preparation of extruded profiles”, “painting prepared cut profiles”, and “packaging finished products”.

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is composed by seven sectors related to the acquisition of composed materials, production/preparation of profiles, packaging of products, and final expedition.

Therefore, the factory has nine specific functional sectors (sub-processes) with the combination of machinery and standardized/universal equipment to perform various operations based on production fluxes/scripts well defined, allowing, whenever necessary, the adjustment of manufacturing activities speed to the demand of finished products. The factory plant and the physical setup are designed by work centers grouped together according to the specific productive sectors to facilitate the manufacturing of the three standardized livestock products, having well-distributed internal halls, adapted to mechanized movement of raw materials, in-process materials, and finished products, as well as the flexibility to produce various quantities and mixes of products, facilitating the operations and functional supervision.

5. FINAL CONSIDERATIONS

The establishment of partnerships/collaborative alliances between productive enterprises, universities, and research centers is fundamental to increase industrial competition. Therefore, the innovative roles must be exhaustively performed by the organizations that require to quick and constantly improve processes and/or make new products or considerably improved available to the consumers' market. This research illustrated part of the activities of a technological cooperation project CNPq-RHAE performed in an important agriculture industrial region of the Center-West portion of Brazil, which initially aimed the development of vegeto-polymeric to be used in products (equipment) for feeding and diet supplement of vitamins and minerals for cattle.

From an adaptation of three initial stages of the methodology "Strategic Structure for the Development of Products", by Clark and Wheelwright, coherent to the performance of the applied research, it was elaborated both the concepts

Factory section key	
Points	Description
A	Section of biling plastic chips
B	Section of processing vegetable fibers
C	Section of granulating plastic chips
D	Section of extrusion of composites, conformation, and cutting profiles
E	Section of preparation of profiles
F	Section of preparing and homogenizing polymeric blends
G	Section of preparing product assembling kits
H	Section of packaging finished products
I	Section of painting cut profiles
J	Warehouse and expedition

Image 7. Factory plant and functional physical setup (reviewed and approved).

Source: The authors themselves.

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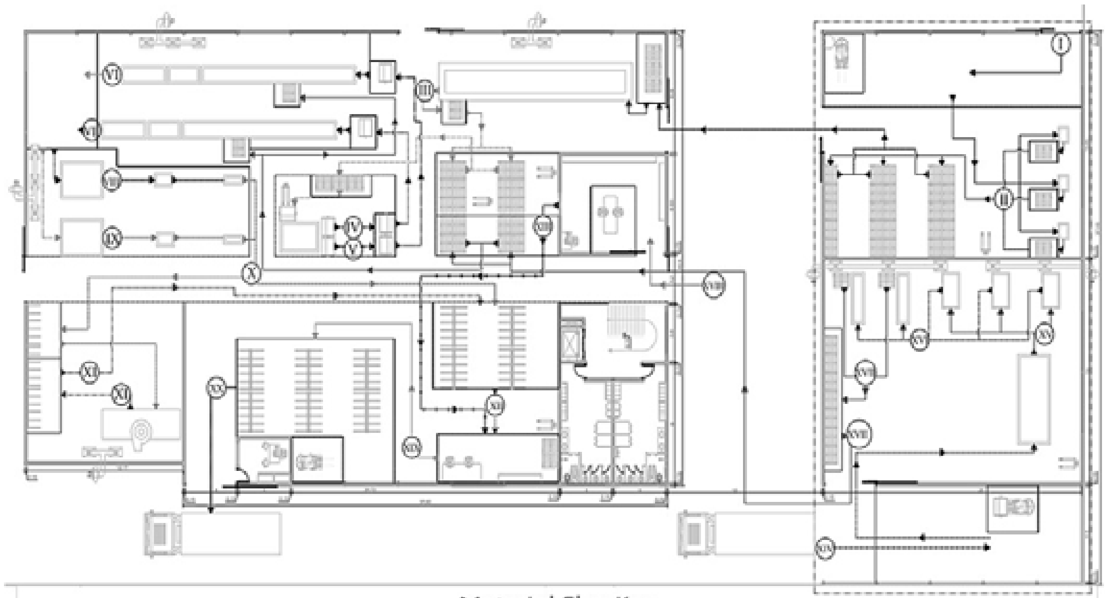

Material Flux Key			
Line	Description	Line	Description
I	Flux of plastic chips	XI	Flux of painted profiles
II	Flux of chip bundles	XII	Flux of prepaired and/or painted profiles
III	Flux of plastic grains	XIII	Flux of assembling kits
IV	Flux of homogenized blends (PE)	XIV	Flux of vegetable fiber
V	Flux of homogenized blends (PP)	XV	Flux of dried vegetable fiber
VI	Flux of cut profiles (PE)	XVI	Flux of crushed vegetable fiber
VII	Flux of cut profiles (PP)	XVII	Flux of processed vegetable fiber
VIII	Flux of profiles (PE) under construction	XVIII	Flux of fixing elements
IX	Flux of profiles (PP) under construction	XIX	Flux of finished products
X	Flux of prepared profiles	XX	Flux of product expedition

Image 8. Process map of the complete productive process.

Source: The authors themselves.

of the three livestock products and the productive system, which is composed by a macroprocess plan (description of sub-processes and operations), list of machinery/equipment, and productive flowcharts, being considered fundamental documents to further implementation of the detailed project of the factory system in a new business unit, with great perspectives to contribute to regional socio-economic development.

At the present moment, the referred composed materials are under industrial patent license in progress at the Brazilian National Institute for Industrial Propriety (INPI), under the title “Process for Building Vegeto-Polymeric Composites” (process code BR 10 2014 018724 3) – the content of technological innovation of the new material refers to a unique industrial process for the processing of composites generated by polymeric blends and reinforcing vegetable fibers. Thus, the industrial waste from INFLEX, which is composed by plastic clips originated from refilling film coils (normal losses of the process), which are reinserted in the operation chain, enabling the manufacturing of new products applied to regional cattle activities.

The characterization of molecular structure and mechanical proprieties of the vegeto-polymeric composites also suggest technical applications different from the regional agricultural sector, where today new ways of using the referred material are analyzed in products destined to the areas of civil construction, automobiles, airplanes, furniture, and rigid packaging, as seen in the patent request sent to INPI.

This study permitted that the operations at INFLUX are even more aligned to the Brazilian National Policy of Solid Waste (Federal Law #12,305/2010), at the same time another productive unit will allow to aggregate value to the residual plastic from the main productive plant. As a conclusion, the research performed inside a context of partnership between a company and the universities involved has shown to be a fundamental instrument to develop/

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apply technological innovations in products and processes, which match present public policies to densify regional productive chains.

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