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Guidelines for a rehabilitation model for banana packing plants from the integration of environmental variables and human factors.

Juan C.Paniagua Carvajal[a], Juliana Sánchez Jaramillo[b], Alexander González Castaño[a]*

[a]*Laboratorio de estudios y experimentación técnica en arquitectura LEET, Universidad Pontificia Bolivariana UPB, Medellín, Colombia*
[b]*PVG Arquitectos, cra 68 49A-29. Of 302, Medellín, Colombia*

Abstract

The banana plantation worker, as the main actor in a manufacturing process that provides 35% of agricultural produce in the country, has been relegated to a working field in spaces conditioned only for productive processes, leaving aside the possibility of designing working environments that consider vital aspects in their workplace, such as the correct dispositions of working planes, visual ergonomics and hygrothermal comfort, factors that affect the well-being, health, and productivity of individuals. The Urabá zone, located in the department of Antioquia, produced, according to data provided by AUGURA, 73% of national banana exports during 2013, positioning itself as the biggest banana zone in the country, which is a relevant condition for the development of this research, which starts with the architectural survey, spatial, functional and working conditions of a banana packing plant (BPP) in the municipality of Apartadó, from which analysis benchmarks of the conditions of the banana production process are established, and fundamental aspects for an optimized rehabilitation plan of BPP´s are identified. The theoretical framework of the research considers the analysis of the environmental conditions in a warm humid climate, workspace and process occupation areas assessment, studyof human factors associated with the stations' operation, and analysis of ergonomic and dynamic anthropometric conditions. The result of this research is a series of rehabilitation guidelines for BPP´s,which influence in the quality of working environments and the productivity of the process.Relevant aspects obtained from this research, will be discussed with the banana producing factories and export companies and those could be projected on production business models, from the architecture, human factors and ergonomic´s.

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*Keywords:*Rehabilitation; Banana packing stations; Bioclimatic Architecture; Human Factors; Ergonomics.

* Corresponding author. Tel.: +57 4 4449483.
*E-mail address:*juan.paniagua@upb.edu.co

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1. Introduction

Colombia is located in a tropical context, which make climatic conditions such as temperature and sunlight a constant throughout the year; in addition, the Urabá zone, within the tropical context, is close to the Caribbean Sea on the Atlantic Ocean, which is a marine waterway used for agro-industrial exports.

Banana exports, as an agro-industrial activity in the Urabá zone, represents 3% of national exports, 35% of Antioquia's exports, and generates approximately 80,000 jobs, 75% indirect and 25% direct. At the same time the zone exports 73% of the national banana production[1], a condition that added to the economic projection of the Urabá zone, corroborates the relevance of this research, finding a particular interest in improving workspace conditions based on systemic sustainability.

Systemic sustainability not only encompasses environmental variables, but also human, social, economic and political dimensions that involve topics related with absenteeism due to occupational disease, long working hours, working postures, payment and contracting, all variables directly related to productivity and the quality of life of banana workers.

The purpose of the research was to assess, through the Case Study method, the diagnosis of a packing station and, starting with this assessment, provide recommendations to design from two fronts: Infrastructure and Ergonomics, and on these two chapters pose guidelines from different intervention scales to approach a rehabilitation model of a banana packing station.

2. Theoretical Framework

Information compilation was the starting point to define the current situation of the process carried out in a Banana Packing Plants (BPPs). The operational definitions of the studied concepts allowed establishing specific benchmarks over which there would be a greater emphasis during the stage of acquisition of field information. Next, definitions, statistical data and different indicators that give sustenance to the research are shown.

Systemic Sustainability: Is defined as the set of variables that not only involve environmental factors, but considers other set of factors that influence a built space; among these factors, there are political, social and economic variables.

Sustainable rehabilitation: Includes the recuperation of an architectural space through interventions that involve variables dealing with systemic sustainability.

Hygrothermal Comfort: Is the quality of thermal sensation in a space.

Micro-climate: Is the set of atmospheric and climatic conditions that involve variables in temperature and humidity in a determined space.

Area of operation: Defined by the dimensions of occupation of the person carrying out an activity; in other words, the area of occupation of the person moving with respect to surfaces and objects with which such person interacts.

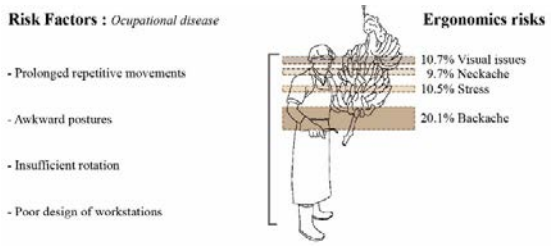

Fig. 1. Risk factors / Ergonomics risks

From the Asociación de Bananeros de Colombia AUGURA (Colombian Association of Banana Producers) research on work environment, responsible water management in plantations, soil management and conservation, biological plague control with vegetable toppings have been made. Regarding the specific topic of ergonomics, a

publication was done on the technique of Desuckering with a special tool, an activity that, though carried out in the plantation, represents a valuable asset to this research project since it poses, through technical criteria, punctual solutions to this activity from the fundamental objective, the well-being of the banana worker. It is worth noting that within all studied documentation, no relevant data was found on activities carried out in the packing station, related to ergonomic and bioclimatic factors, a reason to have used the study case method.

3. Methodology

During the research five banana packing plants were visited, located in the municipalities of Apartadó and Carepa, where technical tours were made to know and analyze the fruit harvesting process, from the plant to its packing. Generally, all BPPs visited keep the same spatial distribution patterns and the general pathologies identified are common in all cases. To carry out more profound studies the San Jacinto Plantation was selected; the main selection criterion was accessibility to information and availability of plant coordinators for compilation of technical data, photographs, analytical observation of the process, and non-structured surveys with workers and supervisors. The farm is located in the rural zone of the municipality of Apartadó; it covers123.79 hectares (305 acres) and has a production capacity of 1,800 boxes by shipment. It has 35 employees in the packing plant and 48 employees in the fields, for a total of 83 workers.

The information collected in photographs, environmental data, videos and comments from plant personnel and related professionals, made it possible to know in detail the particular process of a BPP, and apply, in the selected case study, specific recommendations resulting from the process of analysis of work, environmental and ergonomic improvement. This analysis allowed, at the same time, a general understanding of the banana packing processes that are developed in the region, and its requirements to generate assessment criteria and guidelines for the rehabilitation of other packing plants.

The methodology implemented considers three stages: Visit to the plant and collection of information, Processing of the information, diagnosis, and Proposal.

3.1. Visit to the plant and collection of information

A photographic record of the spaces and the processing in the five BPPs was done. In the selected plant for the thoroughstudy, measurements of spaces were taken, and a table was filled out with environmental requirements of each of the processes referring to sunlight, lighting, ventilation and temperature. In the same manner, a detailed photographic record was made of the activities in the packing plant, and data was recorded regarding: number of people carrying out an activity, working hours, break time, working posture, duration of patterns per minute, repetitions per minute, object manipulated, weight of object manipulated, support tool to carry out an activity, safety equipment, complains or injuries causes.

3.2. Processing of information:

During this stage, information collected in documentary sources and field work was registered.

3.2.1. Architectural survey and simulations

Architectural survey and digital modeling of the space were carried out to verify natural lighting conditions, through computerized simulations that allow recording light levels in work planes. The simulations were carried out using VELUX Daylight Visualizer V.2.8 software [2], with coordinates 76.64W 7.90N, under partly cloudy conditions, characteristic of region. The dates of June 21, March/September 21, and December 21 were evaluated, representative of the solar path, for 8:00, 12:00, and 16:00 hours.

In the same manner, a solar incursion study was carried out to verify incidence of sunlight in working zones. The study was made through the geometric diagram method of shadows on the same dates that the lighting studies were made, for 08:00 and 16:00 hours.

3.2.2. Anthropometric assessment:

For the ergonomic study, 6 activities within the packing plant processes were selected: Dehanding, Selection, Classification and selection, Labeling, Packing and Palletizing.

Criteria for activities selection were: intervention of workers, requirements of traction and pushing efforts, footwork and repetitive actions.

A photographic record was done in which people were portrayed carrying out an activity in a frontal and lateral position, with the camera posted at a height of 1.00 meters to reduce perspective. At least two persons per activity were selected for this sample.

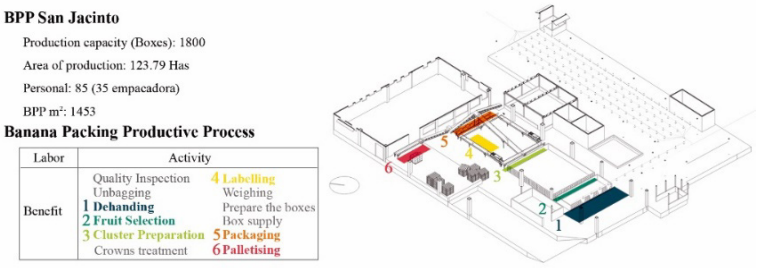

Fig. 2. BPP San Jacinto distribution.

Later, through a graphic process, workplace spaces and people working on their stations were drawn, identifying work space dimensions, lateral, frontal and superior reaching, and areas of operation, in accordance to anthropometric profiles of workers, classified according to anthropometric standards of Colombian working population (ACOPLA 95).

3.3. Analysis and proposal:

Keeping in mind the climatic conditions of the place, environmental requirements for each process in the packing plant, and pathologies identified during visits, the following criteria were established to raise the proposals: humidity control that benefits space microclimate, protection of direct solar radiation over the fruit to prevent premature decay, biological control of rodents and birds, management and canalization of water and organic material in hallways, control of radiant heat by means of cover, and generation of provisional storage areas.

In the same manner, for recommendations to each working post, anthropomorphic variations within the working population of the packing plant were considered.

4. Results

Next, a diagnosis under each analysis category is presented. Later, according to technical and regulatory criteria, design proposals for rehabilitation of packing plants are expressed.

4.1. Infrastructure

4.1.1. Natural lighting

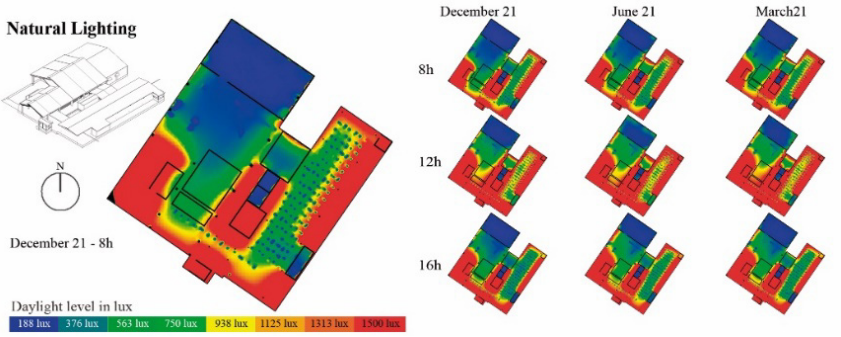

Fig. 3. Natural Lighting diagnosis

As seen in the pictures, the greatest light levels are found in the closest zones to east, south and west fronts, generating high contrast between the center and perimeter zones. On the contrary, the northern zone corresponding to the machinery that produces the packaging has levels under 200Lux for close fronts, thus causing low levels in packaging zones, and high contrast when compared to other plant spaces.Taking into account that some of the activities carried out in the plant require specific light levels due to the type of processes and visual demand, areas susceptible to intervention were identified.

It is important to clarify that the quality processes and fruit selection are made in each stage of the process, and thus necessary to guarantee adequate light levels for product inspection. In accordance to Colombian RETILAP regulations, light levels required for zones of food industry inspection and quality processes must be between 500 and 750Lux. In order to increase light levels taking advantage of natural resources, we propose the provision of skylights in the zone of the machinery that produces the packaging and packing, allowing incoming light, and controlling incoming direct sunlight. In the same manner, a storage zoning is proposed, with the purpose of taking advantage of the lighting contribution of existing openings in the front, seeking that the stored material does not generate shadows on work spaces.

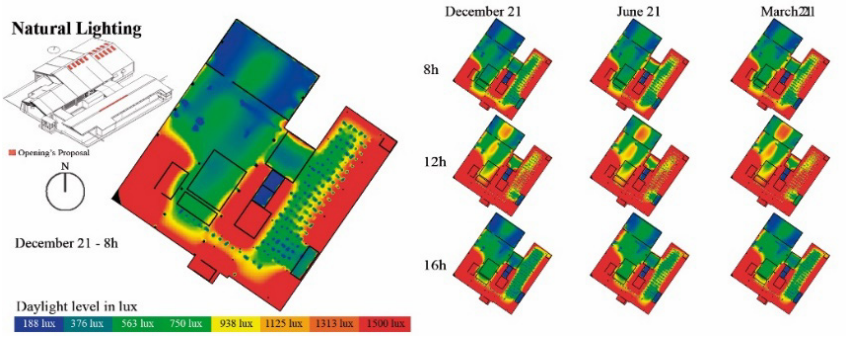

Fig. 4. Natural Lighting Proposal

4.1.2. Sunlight

As seen in the image, 61% of the total work area is affected by sunlight in the assessed hours, increasing the thermal sensation on workers and affecting product quality. The Barcadilla zone (quality inspection), and selection, classifying and packing, are the processes that show being more affected during morning hours. In the case of afternoon hours, the sunlight affects directly the dehanding and palletizing processes.

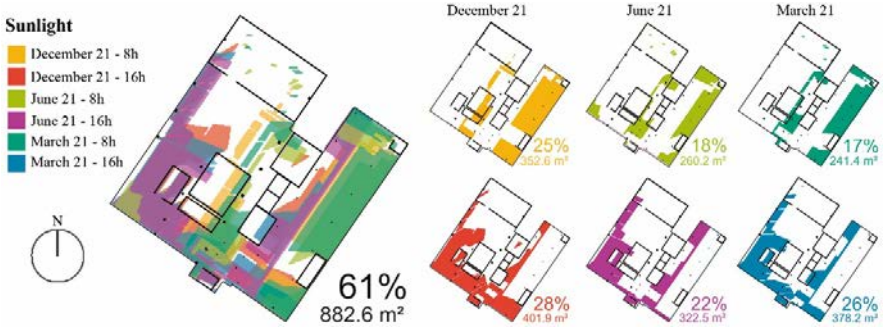

Fig. 5. Sunlight influence.

Having as the main goal to protect fruit from sunlight during the whole packing process, it is suggested to have solar protection elements that do not interfere with cross and convective ventilation processes. This can be achieved through two strategies: Extension of existing covers, and provision of hanging vertical elements from cover.

Exposure of the cover to sunlight produces an increase in room temperature due to thermal accumulation concentrated in fiber-cement covers, reaching surface temperatures up to 70°C in the inside face of roof tiles, and generating a transference process of heat due to radiation that increases thermal perception by the workers and heats air indoors at packing plants. To counter this phenomenon, it is necessary to install a radiant barrier, which purpose is to control heat transfer from the roof tiles, with a low thermal emission factor, present in materials such as aluminum foil paper, which installment process and cost per square meter is approximately 1.5 U$ (González et al, 2000). This solution allows a decrease of up to 6°C in temperature.

The extensive area covered in BPPs allows projecting this zone as an effective area to generate alternative energy by means of photovoltaic panels; in such ways, closed cycles of energy transformation are looked for, which implementation is projected through a cost-benefit relationship, thus including return investment rates, and a decrease in packing plants environmental impact.

4.1.3. Bioclimatic aspects

The architectural space as a container for the activity must be thought of in function of the climatic conditions of the site; because of this, 3 strategies are proposed regarding bioclimatic conditioning:

Adaptation of microclimate through the use of material that allows radiation and humidity absorption, such as gravel or cobbles placed in the plant perimeter. This would generate a transition area between the field and the packing plant to reduce moisture in the environment.

Flood control, especially in areas near water tanks, generating a greater slope in circulation for drainage, and channeling water.

According to international quality certification regarding Good Agricultural Practices, GLOBALGAP, a control to avoid animals from entering agricultural facilities must be implemented. Biological control of these external factors, such as birds and mice, is done by means of an enclosure that allows visibility and crossed ventilation, providing also a pest control in the plant.

4.2. Ergonomics

Coming up next are slides that illustrate physical workspace and workers carrying out their tasks; in addition, operation areas, heights and dimensions of work surfaces, work schedules, tools manipulated during work activities, weight of tools, and repetitions of actions during one minute periods of time are highlighted.

Fig. 6. Physical Workspace Conditions.

As is observed in image (6), dehanding, selection, classification, labelling, packaging and palletizing are activities that present the biggest risks regarding occupational disease, as a consequence of repetitive motions, constant overstrain, bad occupational postures, inadequate tools and equipment, and few pauses during work hours. Considering all of the above, the following strategies are proposed:

4.2.1. Postural change

As an alternative in the same workspaces, conditioning spaces according to activities carried out in them, and the anthropometric profile of possible users.

- Demanding: Even if this is a dynamic activity due to routes and movement involved, a zone for the availability of a sciatic support is proposed to allow breaks during the activity.
- Selection: lower bars as footrests are proposed in order to adopt asymmetrical postures that involve alternating upper limbs to free pressure in feet and lumbar region.
- Classification: It is recommended to implement sciatic support and footrests, and also define afferent areas of the tank for each worker, in order to reduce rotations and displacements.
- Labelling: Implement sloped surfaces for moving trays tray, in order to move surfaces closer to the worker, thus avoiding arm extensions in ftrontal out of reach positions. In the same manner, a sciatic support that allows breaks and postural changes is proposed.
- Palletizing: Implementation of a hydraulic base that guarantees placing of heavy objects at an ideal height, thus avoiding people to bend and unload boxes, or overstraining to pile products in upper parts of the pallet.

4.2.2. Outline of breaks during working hours according to production load.

4.2.3. Automation of moving belts by sections, or change of material for bearings that allow free rolling of trays in order to avoid overstrain due to traction or pushing.

5. Conclusions

The systemic rehabilitation of a banana packing plant (BANANA PACKING PLANTS BPPs), must start from the idea of favoring environmental conditions of space, and an adequate design of workplaces, understanding processes in all activities. This model is proposed as a politically doable economic solution that can be applied not only in the banana production industry, but as a business model in manufacturing and food packaging industries as well.

The total cost of intervention can represent an approximate cost of U$20,000, considering economic quantifiable factors such as the radiant barrier, the enclosure of the packing plant, the skylights, the solar protectors, the ergonomic supports, and the intervention of sloping floors; the automation of transportation belts, the photovoltaic panels, and the hydraulic platforms.

Verification of impact on well-being, health and productivity of the workers, as well as pertinence and viability of the proposals, will be assessed in future researches, when the rehabilitation model of a banana packing plant has been applied.

Recommendations proposed can be classified in three intervention scales, which themselves can be developed by stages, considering the available economic resource.

Table 1. Scale of intervention.

	Organizational	Physical environment	Equipment and Tools
Infraestructure	-Normative GlobalGap enclosure	-Radiant barrier -Skylights -Soil treatment in the perimeter -Waterproof Enclosure -Floor slopes	-Solar Panels -Wind energy
Human Factors	-Active Breaks outline -Workday -Payment outline	-Sciatic support -Footrests -Belts Sloping -Regulated trays	-Palletizing platform -Automated belts by activity

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