




Elaboration, development, and installation of the first animal skin bank in Brazil for the treatment of burns and wounds

Elaboração, desenvolvimento e instalação do primeiro banco de pele animal no Brasil para o tratamento de queimaduras e feridas

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■ ABSTRACT

Introduction: The production and distribution of human skin by Brazilian skin banks is insufficient to meet the country's demand, supplying less than 1% of the need for treating burn victims. The objective of this work was to present the elaboration and development of the first animal skin bank of Brazil for the treatment of burns. **Methods:** This methodological study elaborated, developed, and installed The Aquatic Animal Skin Bank in terms of the development of tilapia skin processing after a systematic review of studies referring to animal skin banks based on visits to the pisciculture center in Jaguaribara-CE, technical visits to human skin banks in Brazil, technical consultation and training in the Recife Skin Bank, the observation of all phases of tilapia skin processing, and the identification of the physical structure of the area where the processes occur. **Results:** In addition to the production and distribution of tilapia skin for studies on burn victims, the bank is processing more than 5000 tilapia skin samples and is in the distribution phase of this skin for multicentric studies in other states and specialties including gynecology, orthopedics, endoscopy, stomatherapy, vascular surgery, dentistry, and veterinary medicine. **Conclusion:** This work enabled the elaboration, development, and implementation of Brazil's first animal skin bank and the world's first aquatic skin bank.

Keywords: Cichlids; Burns; Biological dressings; Biocompatible materials; Tilapia.

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■ RESUMO

Introdução: A produção e a distribuição de pele humana pelos Bancos de Pele do Brasil é insuficiente para atender a demanda do país, suprimindo menos de 1% da necessidade para tratar as vítimas de queimaduras. O objetivo do trabalho foi apresentar a elaboração e o desenvolvimento da implantação do primeiro Banco de Pele Animal do Brasil para tratamento da queimadura. **Métodos:** Trata-se de um estudo metodológico. O Banco de Pele Animal Aquático foi elaborado, desenvolvido e instalado a partir do desenvolvimento do processamento de pele da tilápia, da revisão sistemática de estudos referentes a banco de pele animal, de visitas à piscicultura em Jaguaribara-CE, da visita técnica aos bancos de pele humana no Brasil, de consulta técnica e de treinamento no Banco de Pele de Recife, da observação de todas as fases de processamento da pele de tilápia e da identificação da estrutura física da área onde ocorrem todos os processos. **Resultados:** Além da produção e da distribuição da pele da tilápia para os estudos em vítima de queimaduras, o banco está processando mais de 5000 peles de tilápia e encontra-se em fase de distribuição desta pele para estudos multicêntricos em outros estados e outras especialidades, que desenvolvem pesquisas nas áreas de ginecologia, ortopedia, endoscopia, estomaterapia, cirurgia vascular, odontologia e veterinária. **Conclusão:** este trabalho possibilitou a elaboração, o desenvolvimento e a implementação do primeiro Banco de Pele Animal do país e o primeiro Banco de Pele Aquática do mundo.

Descritores: Ciclídeos; Queimaduras; Curativos biológicos; Materiais biocompatíveis; Tilápia.

INTRODUCTION

A burn is a lesion of organic tissues due to a trauma of thermal origin that varies from a small bubble to severe forms that are capable of triggering systemic responses proportional to lesion extent and depth¹. Lesions can lead to disfiguration, disability and death².

In the Brazilian public network, burns are locally treated with silver sulfadiazine ointment and daily or every other day dressing changes in the vast majority of burn services³. In Europe, the United States, and some countries in South America, this same treatment is performed using human (allograft) or animal (xenograft) skin³. In Brazil, there was never a record of animal skin use in the Brazilian Health Regulatory Agency (ANVISA), nor was it available in the Brazilian National Health System for use in burn patients.

According to the Ministry of Health, Brazil should have 13 skin banks, but only four are currently in working condition in São Paulo, Rio Grande do Sul, Paraná, and Rio de Janeiro; together, they supply less than 1% of the skin needed throughout the country. Without the use of skin, Brazil is 60 years behind in the treatment of local burns, bringing to attention the fact that 97% of Brazilian burn victims do not have a health plan⁴.

Tilapia is among the most consumed fish worldwide, including in Brazil, and the extensive culture of this

captive fish has given rise to the emergence of improved filets; in the production chain, everything is used (viscera, fish bone, and meat) except the skin, of which only 1% is used to produce handicrafts. In 2011, plastic surgeon Dr. Marcelo Borges imagined the possibility of using tilapia skin in the treatment of burns since the supply of skin for treating burns in public hospitals is insufficient and costly.

In 2014, Dr. Edmar Maciel, a plastic surgeon from Ceará State, invited Dr. Marcelo Borges and Ceará researcher Prof. Odorico Moraes to conduct this research in Ceará. Once the initial team was created, the use of tilapia skin was initiated and the skin was developed as an occlusive biological dressing for the treatment of burns, which in turn resulted in the elaboration and implementation of the first Brazilian animal skin bank, the subject of this work.

OBJECTIVE

To present the elaboration, development, and implementation of the first animal skin bank of Brazil to treat burns.

METHODS

This methodological study started in 2015. The elaboration and development of the animal skin bank

are directly associated with tilapia skin development prior to and together with implementation of the aquatic animal skin bank itself, and several stages were performed in the development and establishment of the tilapia skin production process.

Captivity Study

Several visits were conducted by the research team to fish farms in Jaguaribara – Ceará, aiming to discern and study tilapia production, including the establishment of a location for processing and cleaning the skin.

Healing Laboratory Assembly

The Healing Laboratory was constructed in 2015 to produce tilapia skin for future use in animal and human studies. This laboratory is also located in the Nucleus of Research and Development of Medicines of Ceará (NPDM), where the same processes were established in human skin tissues banks for the cleaning, sterilizing, and wrapping of tilapia skin.

Pre-clinical Studies Implementation

Several studies were conducted in 2015 and 2016 with the intent of evaluating the histology, safety, and efficiency of tilapia skin, including a histological study to compare tilapia skin with animal skin⁵, tilapia microbiota study⁶, microbiological test in all stages of tilapia skin preparation, application of tilapia in rats⁷, comparative histological study of irradiated skin⁸, skin toxicity study, laboratory study in animals after skin application, and histological study of healing.

Patent Registration

In 2015, a patent for tilapia skin was registered at the National Institute of Industrial Property (no. BR1020150214359). Abroad, the patent registration was performed in 2016 (no. 00002216016690245).

Animal Skin Bank

At the same time, the following stages were developed for the animal skin bank implementation:

Bibliographical survey: The bibliographic survey was conducted by consulting national and international literature within the PUBMED and Latin American and Caribbean Health Sciences Literature databases. The following resolutions of the ANVISA were used: Resolution of the Collegiate Board RDC no. 220 of December 27, 2006; and Resolution of the Collegiate Board RDC no. 55 of December 11, 2015. The

following descriptors were used in the search: good practices, skin banks, protocols, and flowcharts. The study's inclusion criteria were published in Portuguese, Spanish, or English in books and indexed in the selected databases with the descriptors listed above.

Recognition of the physical area for the animal skin bank assembly: Using the site's ground plan, a survey was performed of all available areas for animal skin processing in which the locations for each processing stage were selected, to establish a continuous flow. A survey of all equipment available on site was also conducted.

Visits to human skin banks: Technical visits were made to skin banks in Recife-PE, Curitiba-PR, São Paulo-SP, Rio de Janeiro-RJ, and Porto Alegre-RS, in which a needs survey of input, sterilization control, and organization of the environment was conducted.

Technical consultant: The head nurse of the Skin Bank in Recife - Professor Fernando Figueira Institute of Integral Medicine was hired as a technical consultant in Fortaleza and subsequently attended an immersion (hands on) session on the chemical sterilization process of tilapia skin in Recife.

Establishment of the sterilization process: After chemical sterilization of some batches of tilapia skin, the researchers visited the Institute of Nuclear Energy Research and, through a research partnership, began the irradiation process after chemical sterilization. To reach the current stage of tilapia skin sterilization, several evaluations with different chlorhexidine and glycerol concentrations and irradiation dosages were required.

Registration and standardization of tilapia skin processes: In this stage, an observational follow-up of the tilapia skin production process was performed from the animal's slaughter in Jaguaribara-CE to skin wrapping in the laminar flow. All processes were recorded in documents and through photographs.

Figure 1 shows the implemented stages up for the creation of the skin bank.

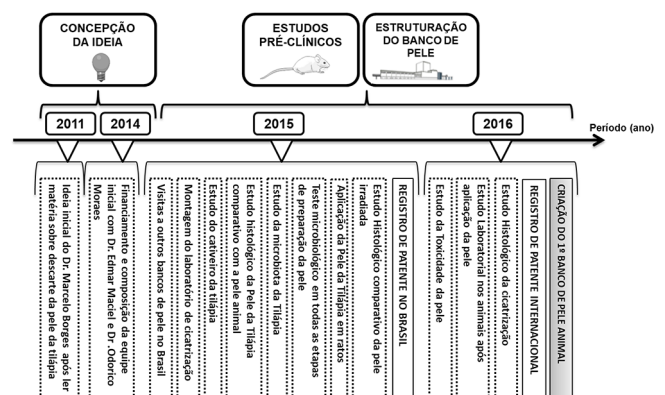


Figure 1. Timeline of the elaboration, development, and implementation of the animal skin bank.

RESULTS

The Aquatic Animal Skin Bank of the NPDM located at the Federal University of Ceará, in Fortaleza, has been operating since 2016 and was inaugurated in 2017. Its first production run included 250 skins. In addition to producing and distributing tilapia skin for the studies of burn victims, the bank has processed more than 5000 Nile tilapia skins (*Oreochromis niloticus*) and is in the skin distribution phase for multilevel studies in other states (SP, GO, PR, and PE) and other specialties including gynecology, orthopedics, endoscopy, stomatherapy, vascular surgery, dentistry, and veterinary medicine for the reconstruction of vaginas, varicose ulcers, pressure wounds, and dog wounds as well as in experimental animal studies as a possible *scaffold*.

The Bank team consists of an administrative medical director, technical medical director, chief nurse, two nurses, nursing technicians and assistants, and medical and nursing students.

The physical space includes two clean rooms with laminar flow for the tilapia skin sterilization process following the classification standards required by the ANVISA for human studies.

Standardization of tilapia skin processing

The tilapia skin improvement process is divided into seven stages:

Stage 0 – Organization and assembly of the Healing Laboratory and the Animal Skin Bank before the arrival of the skins;

Stage 1 – Processing and transport: Ensuring proper collection of skins at fish farms and transporting them in isothermal boxes to the laboratory;

Stage 2 – Cleaning and decontamination: Cleaning and withdrawal of excess dermal muscle and clipping of skin borders;

Stage 3 – 2% chlorhexidine decontamination;

Stage 4 – Chemical sterilization in 75% glycerol;

Stage 5 – Sterilization in 100% glycerol in a water bath; and

Stage 6 – Double wrapping, double sealing, labeling, and inventory (performed in the laminar flow cabin).

From Stage 6, the processed and identified skins are conserved under refrigeration at 2–4°C in a refrigerator designated for non-released tissues awaiting the microbiological result. These skins are identified and catalogued using Cartesian numbering in ascending order and sent to the Institute of Nuclear Energy Research in São Paulo, where they are irradiated to 30 kGy and sent back to the laboratory of origin (Healing Laboratory – NPDM), where they are stored in a refrigerator for released tissue for use

at 2–4°C. After these stages, the skins are valid for use for up to 2 years.

Some of the processing stages are shown in Figures 2a and 2b.



Figure 2A. Cleaning and preparation of the tilapia skin by the responsible team.



Figure 2B. Tilapia skin prepared and packed by the team.

After obtaining the tilapia skin with double wrapping, the researchers were not satisfied; to facilitate transportation to other states and countries, besides decreasing the cost since it is meant to be a product that can be on the shelf, they developed lyophilized tilapia skin.

Another completed stage is the removal of skin cells from the tilapia for use as an acellular dermal matrix of a *slings* and *scaffolds* in diverse areas. As soon as animal studies are completed, this *scaffold* can be used in numerous medical specialties, such as gynecology (uterine and bladder lifting and pelvic floor repair), plastic surgery (breast reconstruction and fat grafting), general surgery (hernias), traumatology (tendon injuries), and tissue loss.

The Aquatic Animal Skin Bank is in the documentary preparation phase, in which protocols, flowcharts referring to each processing stage, checklists, and a flowchart map are developed, to standardize all procedures and verify if they are being complied with as recommended. Hence, the researchers ensured that the facility met regulatory standards to facilitate the installation process of future aquatic skin banks that can be installed in the country and abroad.

DISCUSSION

Information about the use of cadaver skin in the literature was first published in 1903⁹ by Wentscher, who kept the skin refrigerated for 7 days. Conversely, the first record of animal skin use was published in 1952¹⁰ by Keeley, who conducted and published an experimental study with dog skin, showing the effects of freezing, vitrification, and dehydration. In 1955, James Barret Brown¹¹ laid the foundation for organizing a skin bank in terms of physical structure and skin conservation methods.

In Brazil, the first skin bank was established in the 1980s, functioning in the early stages at the Clinical Hospital (HC) in São Paulo. The current HC skin bank was created in 2000, renovated in 2006, and reopened in 2012. Unfortunately, the amount of skin provided by skin banks that are currently operating in Brazil falls far short of the requirement for burn treatment.

Since its inception, the Aquatic Animal Skin Bank of the NPDM has processed more than 5000 Nile tilapia (*Oreochromis niloticus*) skins. It is becoming an increasingly more viable option to meet the country's skin demand in the treatment of burns, as research has shown positive results in various clinical settings. The raw material is a byproduct of tilapia processing and presents another advantage of being less costly than conventional silver sulfadiazine treatment.

Given this point of view, the Aquatic Animal Skin Bank must comply with the regulatory standards required by the regulatory agencies since the ANVISA abides by the Collegiate Board Resolution RDC no. 55 of December 11, 2015¹², which provides Good Human Tissue Practices for therapeutic use as a guideline to ensure tissue quality and safety for therapeutic use. This applies to all tissue banks of any nature that perform activities with one or more types of human tissue for therapeutic purposes¹³. Given this, because it is a tissue with applicability in humans, the release and use of tilapia skin is subjected to strict protocols to ensure the recipient's health.

The challenges to the first Brazilian Aquatic Animal Skin Bank involves adapting established rules for human donor skin banks to process skin extraction from an animal, mainly because it is a novel concept

in Brazil, where it will probably be used as a standard model to be replicated domestically and internationally.

Finally, in addition to the innovation in the development of an invaluable clinical use product derived from tilapia processing, its initial objective of fulfilling the demand for skin for burn treatments has now a large array of possibilities. In terms of the therapeutic applicability of tilapia skin, the results of this work also place Brazil in a prominent position as a pioneer in the production of this type of material and the first country to have an aquatic animal skin bank.

CONCLUSION

This work allowed the creation of Brazil's first animal skin bank with structure, elaboration, and standardization of all procedures for the production of tilapia skin.

COLLABORATIONS

EMLJ	Data Curation, Final manuscript approval, Funding Acquisition, Investigation, Project Administration, Realization of operations and/or trials, Supervision
MOMF	Conception and design study, Project Administration, Supervision
MBSR	Final manuscript approval, Supervision, Writing - Original Draft Preparation, Writing - Review & Editing
FRSJ	Data Curation, Realization of operations and/or trials
CMPL	Data Curation, Realization of operations and/or trials
MFAN	Data Curation, Realization of operations and/or trials

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