TECHNOLOGIES FOR SUSTAINABLE FROG FARMING

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ABSTRACT: Sustainability in a rural production establishment refers to the ability of the activity to generate income for the rural producer without depleting natural resources, while respecting the environment and utilizing the production space efficiently and optimally. Frog farming requires the use of a significant natural resource that must be preserved and managed responsibly. This paper aims to present and discuss current technologies and techniques that can promote sustainable frog farming. Among the technologies developed in frog farming, the following stand out: the frog-rearing system using recirculating water, which has shown good production rates; the raising of frogs in a polyculture system with Nile tilapia, which offers small producers an option to diversify production and make more efficient use of breeding space; research evaluating the nutrient digestibility of various bullfrog feeds; and the inclusion of non-traditional ingredients commonly available on small farms (banana, pumpkin, and avocado) in bullfrog tadpole diets, as feeds formulated based on species-specific nutrient digestibility coefficients help reduce organic waste and improve water quality. Additional advances include technologies for reproduction and the evolution of bullfrog growth rates in recent years. These techniques, together with information obtained through research, contribute to the development of a profitable, sustainable, and environmentally friendly frog farming system.

KEYWORDS: frog farming; nutrition; production; reproduction; sperm; weight; wetland.

TECNOLOGIAS PARA UMA RANICULTURA SUSTENTÁVEL

RESUMO: A sustentabilidade em um estabelecimento de produção rural é a capacidade da atividade em gerar renda ao produtor rural sem esgotamento dos recursos naturais, respeitando o meio ambiente, utilizando o espaço de produção da melhor forma com eficiência. A ranicultura utiliza em quantidade um recurso natural muito importante ser preservado e cuidado.

O presente trabalho foi elaborado com objetivo de mostrar e discutir como tecnologias e técnicas existentes e atuais que podem levar a ranicultura a ser sustentável. Dentro das tecnologias desenvolvidas na ranicultura destacam-se o sistema de criação de rãs em recirculação de água que apresentou bons índices produtivos, criação de rãs em sistema de policultivo com tilápia do Nilo que surge como opção para pequeno produtor diversificar a criação e uso mais eficiente do espaço de criação, pesquisas que avaliaram a digestibilidade de nutrientes de vários alimentos para rã-touro e a utilização de ingrediente não tradicionais comuns em pequenas propriedades (banana, abóbora e abacate) para dietas de girinos de rã-touro, pois rações elaboradas a partir dos coeficientes de digestibilidade dos nutrientes específicos para espécie contribuem para diminuição de resíduos orgânico e para melhoria da qualidade da água, tecnologias utilizadas na reprodução e a evolução do crescimento da rã-touro nos últimos anos. Todas essas técnicas desenvolvidas e informações obtidas pela pesquisa contribuem para construção de uma ranicultura lucrativa, sustentável e que respeitam o meio ambiente.
PALAVRAS-CHAVE: alagado; espermatozoide; nutrição; peso; produção; ranicultura, reprodução.

INTRODUCTION

Although frog farming began in Brazil 90 years ago, the activity still faces several obstacles in its production chain. Among these, the absence of a public or private genetic breeding program stands out. In most cases, breeder selection within frog farms has been conducted without zootechnical criteria.

One way to detect changes in the growth pattern of frogs in Brazil is through scientific studies on growth curves and production performance, in addition to information obtained from frog farmers.

In animals without dietary restrictions, the relationship between weight and age or time results in a sigmoid growth curve, comprising three distinct phases: an initial accelerated phase, a linear intermediate phase, and a final deceleration phase when the animal reaches maturity. Growth rate (weight gain per unit of time, generally in g or kg day^{-1}) varies with age, increasing during the accelerated phase until reaching a peak in the intermediate phase, where it remains relatively constant. In the final phase, the growth rate progressively decreases to zero as the animal reaches its mature or asymptotic weight (Pereira et al., 2015).

The production chain needs to be supported by technological knowledge that enables ecologically sustainable production, ensuring the desired quality and productivity, and facilitating the action and expansion of other links within it. The development of frog farming in Brazil is limited by factors such as the lack of technical information for management during the reproductive phase (Pereira et al., 2013).

Inadequate management during this phase results in irregular supply and inconsistent size of the animals sold. A lack of basic knowledge about reproductive parameters has led frog farmers to oversize their breeding facilities and maintain excessive breeding stock. Moreover, fluctuations in production hinder the development of a zootechnical plan for managing the breeding flow from spawning to slaughter.

The induced reproduction technique (Agostinho et al., 2000) enables the supply of high-quality, abundant, and scheduled spawn according to reproductive planning, as well as the incubation and hatching of eggs under climatic conditions favorable to offspring performance (Pereira et al., 2017).

Additionally, the genetic structure of bullfrog populations in Brazil shows limited variability, a consequence of the small number of introductions and founders. This limitation can be addressed with a breeding selection program and the adoption of artificial fertilization techniques that allow targeted crossbreeding between different genetic groups. However, artificial fertilization requires effective protocols to assess gamete quality.

Sustainability in a rural production establishment is the ability to generate income for rural producers without depleting natural resources, while respecting the environment and optimizing the use of production space.

Frog production in Brazil includes small, medium, and large producers. However, most are small-scale, particularly in the state of Rio de Janeiro, one of the largest producers of frog meat, where production is largely carried out by small farmers, many of whom use it to supplement their farm income (Esteves et al., 2023).

When the term sustainability is used, it usually refers to environmental concerns; in the context of national frog farming, it specifically applies to the production of bullfrogs, an exotic species. Producing this species helps reduce poaching of native species, but its release into the wild should be prevented to avoid negative environmental impacts.

In Brazil, several research and educational institutions develop technologies primarily for small-scale frog farmers, such as the Rio de Janeiro State Fisheries Institute Foundation, the São Paulo Fisheries Institute, the Aquaculture Center of São Paulo State University, and the Federal University of Viçosa, among others.

The technologies developed by the project primarily address nutrition, production systems, reproduction, and wastewater treatment.

OBJECTIVE

This study was conducted to demonstrate and discuss existing technologies and techniques that can make frog farming sustainable.

DISCUSSION

Among the various nonlinear equations, the most prominent are the Gompertz, Logistic, Von Bertalanffy, Brody, and Richards equations, as they have been used to represent growth curves for various domestic animal species (Pereira et al., 2015).

In frog farming, studies on bullfrog growth curves have included adjustments using the Gompertz model (variation 1: $Wt = Wm\ e\ (-\ e\ (-\ b\ (t - t^*)))$ or variation 2: $Wt = Wm\ e\ (-\ k\ e\ (-\ b\ t)))$ and the Logistic model ($Wt = Wm \times (1 + e\ (-\ b\ (t - t^*)))^{-1}$). The parameters for the Gompertz and Logistic models are: Wt = weight over time (g); Wm = weight at maturity (g); b = relative growth rate (g/day); k = integration constant; t = time (day); and t* = time (day) at which growth rate is maximum.

The first bullfrog growth curve described was for animals raised in an amphifarm system (*"Anfigranja": housing with a dry area containing feed troughs and shelters for environmental comfort, resembling poultry farms*), resulting in the model $Wt = 321.0\ e\ (-\ e\ (-\ 0.0061\ (t - 142.8^*)))$ using the Gompertz equation (Ramos, 2000).

The second growth curve, also for animals in an amphifarm system and aimed at evaluating other nonlinear models, showed the best fit with the Gompertz equation: $Wt = 334.6\ e\ (-\ 2.9463\ e\ (-\ 0.0137\ t))$.

The third adjusted growth curve for live weight (g) in bullfrogs was obtained in a versatile system (amphifarm with modifications) and aimed to determine growth curves for other organs and body parts. The best fit was achieved with the Logistic equation: $Wt = 343.7\ (1 + e\ (-\ 0.0313\ (t - 109.5))^{-1}$ (Pereira et al., 2014).

The most recent adjusted growth curve was for breeders from a small frog farm, with the objective of evaluating growth for breeding animal selection in a flooded rearing system. The adopted equation was the Gompertz model: $Wt = 656.9\ e\ (-\ e\ (-\ 0.0138\ (t - 173.3)))$ (Pereira et al., 2021).

When the four bullfrog growth curves from Brazil are plotted together, changes in growth patterns over the years become evident, with weight increasing up to 225 days of rearing, and the curves showing a more pronounced acceleration pattern over time (Figure 1).

The main difference among the four live weight growth curves is the superiority of the three most recent curves compared to the first one described (Ramos, 2000). These gains are due not only to selection and genetic changes over the years, but also to significant changes in rearing systems (flooded systems), nutrition (extruded feed), and feeding practices (automatic feeders) in recent years.

Comparing the equation parameters for each bullfrog live weight (g) growth curve reveals a progressive increase over the years (Ramos, 2000; Rodrigues et al., 2007; Pereira et al., 2014; Pereira et al., 2021). However, for the relative growth rate (parameter b), the third curve (Pereira et al., 2014) reached slaughter weight (frogs weighing 250 to 300 g) earlier than the others.

It is important to note that the bullfrog is an anuran amphibian whose physiology, growth, and performance depend directly on environmental temperature (Braga and Lima, 2001). Thus, although these curves were obtained under the best conditions available at each experimental site, variations such as temperature must always be considered in frog farming.

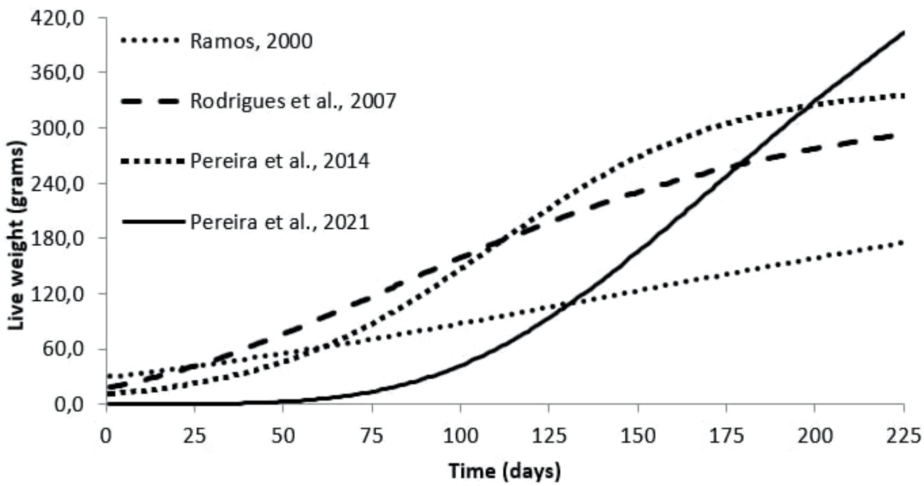

Figure 1 – Live-weight (g) growth curves of bullfrogs (*Aquarana catesbeiana*) between 2000 and 2021, in Brazil.

The lack of basic knowledge, especially on frog reproduction, hinders the use of this technique. Reproductive seasonality (spring-summer) limits production schedules, as tadpole and imago production occurs only during a few months of the year. Consequently, rearing sheds and tadpole tanks remain empty for several months (Leal and Pereira, 2021).

Improving reproduction manipulation techniques—by identifying the optimal time for hormonal induction, determining the appropriate dose, and defining temperature, photoperiod, and other abiotic factors—could increase the production of high-quality tadpoles and imagos (Pereira et al., 2013).

Such information could guide new experiments, improve cultivation conditions, expand tadpole availability for aquaculture, and enhance the economic value of the activity (Pereira et al., 2012). Tadpole and imago mortality remains a bottleneck in frog farming.

Therefore, accurate information on appropriate facilities and management techniques for the different production phases is crucial for the development of this activity.

Among these information needs, a key factor for artificial fertilization is semen quality. In the few studies on artificial fertilization in bullfrogs, fertilization rates and other evaluation parameters vary greatly, possibly due to differences in male gamete quality. The Manual for Andrological Examination and Evaluation of Animal Semen (CBRA, 2013) provides no basic information or routine for male bullfrogs; instead, procedures are typically adapted from fish (Pereira et al., 2013).

Evaluating the reproductive fitness of a breeding male involves assessing general health, genetic health, and the condition of the genital system. Such evaluations should include: selection and marketing of breeding animals, assessment of reproductive potential before and during the breeding season, diagnosis of fertility problems, determination of puberty onset, *in vitro* semen preservation, and others (CBRA, 2013).

Since there is no protocol for evaluating bullfrog semen, as exists for numerous other domestic animal species, research studies typically measure seminal volume and assess sperm concentration (Agostinho et al., 2000). Few studies have evaluated these parameters; instead, most have subjectively assessed sperm color, vigor, and motility (Pereira et al., 2013; Pereira et al., 2017; Leal and Pereira, 2021). Only two studies have examined bullfrog sperm morphology (Tortelly Neto, 2006; Pereira et al., 2013).

Sperm were classified as follows: normal, major defects, minor defects, abnormal head, midpiece, and tail, fractured or coiled tail, macrocephaly, normal isolated head, proximal or distal cytoplasmic droplets, and bent tail (Tortelly Neto, 2006; Pereira et al., 2013).

For the frog farming production chain to expand, a genetic selection and breeding program is necessary. However, this also requires more efficient artificial fertilization techniques. Among the numerous necessary improvements, a semen evaluation routine must be developed.

Several frog breeding systems have been developed over the past 40 years. The most prominent in the 1980s and 1990s was the amphifarm system. In recent years, the wetland system, where animals are kept in water 24/7, has shown excellent production indicators, such as an apparent feed conversion rate of 1.2 kg/kg (Pahor Filho et al., 2019).

To make the wetland system more sustainable, particularly in terms of water conservation and wastewater treatment, a frog-rearing wetland system with recirculation and wastewater treatment was proposed. It consists of a frog pen with wastewater outlets leading to a system with a mechanical solids filter, solids settling tanks, an anaerobic filter, and an aerobic filter. The treated water is then returned to the animal tanks. This system achieved weight gains of 0.79 to 2.40 g/day and an apparent feed conversion rate of 1.1 g/g for growing frogs (Mello et al., 2016).

Recirculating aquatic systems for amphibians or fish require higher electricity consumption due to water pumps; however, solutions such as installing solar panels on farm roofs can reduce this cost.

Water is a renewable resource that is extremely important for frog farming in all rearing phases, both for frogs and tadpoles. Therefore, maximizing its use and the rearing environment is important. Polyculture, a well-established aquaculture practice, consists of raising two or more species together in the same space, using them collaboratively rather than competitively. In frog farming, the identified option is to raise bullfrog tadpoles with Nile tilapia fingerlings (Sarturi et al., 2021).

Polyculture aligns well with the concept of sustainability, as it encompasses both environmental and economic benefits. It is particularly advantageous for small-scale farmers, supporting product diversification on small properties.

In polyculture with bullfrog tadpoles and Nile tilapia fingerlings, two conditions must be met: the amphibians must be larger in length (cm), and the stocking ratio should be one fingerling for every ten tadpoles (Sarturi et al., 2021).

Adequate feeding and nutrition for tadpoles and frogs are essential not only for optimal growth and production rates but also for maintaining water quality. Feeding animals with diets that meet their nutritional requirements improves digestibility and, consequently, reduces solid waste (Seixas Filho et al., 2022).

Several animal- and plant-based ingredients have been evaluated for their digestibility in frogs, including digestible energy, protein, and amino acids (Mansano et al., 2020). This information is essential for formulating commercial frog feeds, as no feed currently exists that is specifically designed to meet the species' nutritional requirements. This is due to the low demand and small-scale feed consumption in this activity, which is not yet of interest to the agribusiness sector.

In aquatic animal feed production, traditional ingredients such as soybean meal, corn, and fish meal are commonly used. However, non-traditional ingredients such as pumpkin, avocado, and banana flours, obtained from high-quality raw materials discarded by food distribution units due to appearance issues, have also shown good performance in bullfrog tadpole diets (Seixas Filho et al., 2022).

These flours, produced from discarded raw materials, are in line with sustainability principles by promoting the optimal use of resources, reducing waste, and reusing materials that would otherwise be discarded.

FINAL REMARKS

The techniques developed and information obtained through research contribute to sustainable frog farming practices that respect the environment. Positive changes in bullfrog growth patterns (g) have been observed in recent decades in Brazil, e.g., faster growth and higher weights compared to previous periods. Although few scientific studies exist on this topic, there are parameters and protocols that can be followed to assess bullfrog semen quality.

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