RESUMO SIMPLES - ECTOPARASITOS: SISTEMÁTICA, EPIDEMIOLOGIA E CONTROLE

DESIGN OF NANOTECHNOLOGICAL FORMULATIONS CONTAINING BIOACTIVE COMPOUNDS: ADVANCES IN THE CONTROL OF ECTOPARASITES IN COMPANION ANIMALS

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Companion animals are susceptible to infestations by ectoparasites, such as the flea Ctenocephalides felis felis and the ticks Rhipicephalus linnaei and R. sanguineus. These parasites have high medical-veterinary relevance, as they directly impact animal health and welfare and act as vectors of zoonoses, thereby also constituting a public health threat. Traditionally, control is carried out using synthetic chemical products—methods whose effectiveness is well-

recognized but increasingly limited due to toxicity to animals and owners, environmental impact, and heightened parasitic resistance. Accordingly, there is a growing demand for disruptive and innovative solutions, such as the application of nanotechnology based on the use of nanoemulsions containing essential oils and their major constituents, which offer natural and sustainable alternatives, with the potential for increased bioavailability and enhanced formulation stability. In this context, the objective of this study was to develop nanoemulsions for future incorporation into topical nanotechnological formulations, using eugenol as a strategic bioactive with proven antiparasitic activity, and to propose predictive mathematical models for hydrodynamic diameter (HD) and polydispersity index (PDI). The experimental design comprised the preparation of nanoemulsions containing eugenol, a surfactant blend (1:1), and water in different proportions, employing two methods: ultrasonication (high energy) and self-emulsification (low energy). The formulations were defined using 2^2 and 2^3 factorial designs with three central points for each technique (n=7 and n=11, respectively). For ultrasonication, the independent variables investigated were eugenol concentration (10–20%) and surfactant concentration (5–10%), with the mixture magnetically stirred prior to ultrasonication. For self-emulsification, the same variables were considered, with the addition of magnetic stirring time (4–12 hours). The dependent variables, HD and PDI, were determined in sextuplicate by dynamic light scattering (DLS) (Zetasizer, Anton Paar) at a 175º angle. Nanoemulsion stability was assessed in graduated cylinders, quantifying the emulsified fraction relative to the total volume after resting. Nanoemulsions obtained by self-emulsification exhibited HD values ranging from 131.23 to 194.66 nm (158.44 ± 23.10 nm), PDI from 7.81 to 25.41% (19.54 ± 5.60%), and variable stabilities (88-100%); meanwhile, those produced by ultrasonication resulted in larger droplets, 246.44 to 550.20 nm (399.59 ± 97.65 nm) and PDI between 21.04 and 29.37% (26.75 ± 2.73%), all showing physical stability (100%). Both techniques revealed statistically significant effects of the independent variables and their interactions; however, it was not possible to propose robust predictive models for HD and PDI in self-emulsification, whereas only diameter could be predicted for ultrasonication. The inability to propose predictive models is likely a reflection of the restricted range of variables tested, although prior experiments showed that expanding the range substantially compromises stability, making incorporation into formulations unfeasible. Despite the limitation in prediction, the developed nanoemulsions demonstrated satisfactory stability and practical potential. In conclusion, this study demonstrated that both techniques enabled

the production of eugenol nanoemulsions compatible with parameters recognized in the literature (HD up to 500 nm, PDI < 30%), with self-emulsification highlighted by its more homogeneous profile, smaller diameter, and satisfactory stability. Ongoing studies include the development of synergistic nanoemulsions containing eugenol in association with carvacrol, as well as the evaluation of the in vitro and in vivo efficacy of the resulting final formulations. Ultimately, this work represents a significant biotechnological breakthrough in veterinary sciences, combining nanotechnology, the strategic use of natural bioactives, and the pursuit of more effective and sustainable formulations. It contributes to the development of innovative, technological, and distinctive alternatives for ectoparasite control in companion animals, driving the promotion of animal health and welfare.

Palavras-chave: veterinary biotechnology; ectoparasiticides; natural products; integrated control; veterinary drug.