Texture profile of filmogenic solutions with potential application for seed biodegradable coatings

Perfil de textura de soluções filmogénicas com potencial aplicação de revestimentos biodegradáveis de sementes

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ABSTRACT

Seed coating has been used in order to minimize environmental and human health damage generated by the use of conventional treatments. Therefore, the aim of this work was to evaluate the influence of the contents of cassava starch (0.5 and 5% (m m^{-1})), glycerol (5 and 50% (m m^{-1})) in relation to the starch mass, and pH (5.5 and 6.5) on the texture parameters (hardness, adhesiveness, fracture, cohesiveness, elasticity and gumminess) of filmogenic solutions with the potential to prepare seed coatings. The adhesiveness, cohesiveness, elasticity and gumminess, were influenced by the variables in the studied range. In order to evaluate the coatings produced on seed germination, future work is necessary.

Keywords: Seed Treatment, Nanoemulsion, Essential Oil, Thyme.

RESUMO

O revestimento de sementes tem sido utilizado de modo a minimizar os danos ambientais e para a saúde humana gerados pela utilização de tratamentos convencionais. Portanto, o objectivo deste trabalho foi avaliar a influência do conteúdo de amido de mandioca (0,5 e 5% (m m-1)), glicerol (5 e 50% (m m-1)) em relação à massa de amido, e pH (5,5 e 6,5) nos parâmetros de textura (dureza, aderência, fractura, coesão, elasticidade e goma) das soluções filmogénicas com potencial para preparar revestimentos de sementes. A adesividade, coesividade, elasticidade e goma, foram influenciadas pelas variáveis da gama estudada. A fim de avaliar os revestimentos produzidos na germinação das sementes, é necessário um trabalho futuro.

Palavras-chave: Tratamento de Sementes, Nanoemulsão, Óleo Essencial, Tomilho.

1 INTRODUCTION

The seed is the basic input of agricultural production, and its association with pathogens can generate a series of damages capable of harming the establishment and development of different cultures (PEREIRA et al., 2015). Seeds infested with pathogens can be a mean of entry for these organisms in areas of cultivation, which can reduce their germination power and vigor, decreasing agricultural productivity and increasing the final cost of crops. In addition to using seeds of good genetic, physical and physiological quality, phytosanitary treatment is essential to obtain good plantations (LIMA et al., 2020; MACHADO et al., 2006; PEREIRA et al., 2015; SHARIF et al., 2018). Hence, the search for solutions has become dependent on chemical control (SARANGAPANI et al., 2017), which in addition to leading to the evolution of pest resistance, can cause several damages to the health of the farmer, biodiversity and the environment (CAMPOS et al., 2018; PAN et al., 2013). In this way, the practice of treating seeds with new active ingredients is important to minimize the risk of developing resistance in soil pathogens (LAMICHHANE et al., 2020).

Seed treatment using biodegradable coatings enables the use of a relatively small amount of active ingredients applied, protecting seeds during their germination as well as their roots and shoot after emergence (SCHOENINGER & BISCHOFF, 2014; WAQUIL et al., 2005). Conventional seed treatment presents limitations in relation to the products being applied, in many cases there are risks to the environment and the health of operators, due to dust and handling of toxic products. Accordingly, the coating process has been an efficient method, as it allows combining active ingredients with other products on the seed surface (MACHADO et al., 2006; RAKESH et al., 2017). Seed treatment using biopolymers-based coating can bring several benefits as it serves as a vehicle for nutrients, growth regulators, and antimicrobial agents, among others. Besides that, it presents a firm adherence, avoiding loss of added ingredients, reducing product leaching to water sources and decreasing the dust generated by the applied products (AVELAR et al., 2012).

Among the most promising biopolymers for the production of coatings are starches from several botanical sources, which present low cost and high availability (ARIENTE et al., 2005; MALI et al., 2010). The interest in the use of biodegradable polymers in the development of coatings, besides being associated with the reduction in the use of synthetic materials that present slow degradation in the environment, is also related to the use of renewable raw materials, especially those derived from agricultural products (OLIVEIRA, AF et al., 2009). The incorporation of plasticizers into the polymeric matrix can improve the flexibility of the material, however, the plasticizer / polymer ratio must be considered, since high concentrations of plasticizer reduce barrier properties (VERSINO et al., 2016).

Products such as essential oils (EOs) can also be incorporated into the polymeric matrix as alternatives to replace conventional chemical products, as they present, among others, antifungal and antibacterial properties (CHOUHAN et al., 2017), and their incorporation in coatings is facilitated by the formation of nanoemulsion.

The aim of the present work was to study the influence of pH, content of cassava starch and glycerol on the texture parameters of filmogenic solutions containing thyme EO nanoemulsion in order to contribute with relevant information for the development of technologies for seed treatment.

2 MATERIAL AND METHODS

2.1 MATERIAL

The cassava starch (Matuto batch brand MT149) was purchased in local stores in the city of Alegre-ES. Glycerol (batch 65656) was purchased from Dinâmica Química Contemporânea Ltda® and the essential oil (EO) of thyme (Thymus vulgaris L.) (batch BJ62640) was purchased from Quinari®.

2.2 EXPERIMENTAL DESIGN

In order to verify the relationship between cassava starch (0.5 and 5 g), glycerol (5 and 50 g in relation to the starch mass), pH (5.5 and 6.5), and the texture properties of filmogenic solutions (SF) (hardness, adhesiveness, fracture, cohesiveness, elasticity and gumminess), a response surface methodology was applied. A complete factorial design (2^3) was used, with the performance of eight tests. The actual and coded values of the levels of the independent variables are described in Table 1.

Table 1. Actual and coded values for starch, glycerol and pH used in planning.

FS	Encoded values			Actual values		
	Fec. (%)	Gli. (%)	pH	Fec. (%)	Gli. (%)	pH
1	-1	-1	-1	0.5	5	5.5
2	-1	-1	1	0.5	5	6.5
3	-1	1	-1	0.5	50	5.5
4	-1	1	1	0.5	50	6.5
5	1	-1	-1	5	5	5.5
6	1	-1	1	5	5	6.5
7	1	1	-1	5	50	5.5
8	1	1	1	5	50	6.5

FS= filmogenic solution; Fec. = Starch; Gli= Glycerol in relation to the starch mass.

The influence of independent variables on dependent variables was verified according to their significance and / or interaction. The response surface graphs and mathematical models were adjusted ignoring the effects that were not significant considering the adjusted R^2 value. The non-significant effects that raised the adjusted R^2 value were maintained in the equation.

2.3 PREPARATION OF THE FILMOGENIC SOLUTION

Filmogenic solutions (FS) were prepared according to the methodology proposed by Carvalho (2010). For each treatment, starch and glycerol were added in deionized water, adjusting the pH to appropriate values, using 0.1 mol L^{-1} NaOH or glacial acetic acid. The suspension was stirred and heated slowly on a heating plate with continuous magnetic stirring until gelatinization of the cassava starch. The FS obtained were kept at this temperature for five minutes and, subsequently, cooled to room temperature to incorporate the thyme EO nanoemulsion to obtain a final solution at 10,000 ppm.

2.4 TEXTURE CHARACTERIZATION

The evaluation of the FS texture profile was performed in a Brookfield CT-3 texturometer device, and the data acquired through the TexturePro CT software version 1.4. For the analysis, a cylindrical acrylic probe of 1.0 in diameter was used. The probe was inserted into a 50 mL beaker containing 40 mL of FS. The pre-test, test and post-test speeds were 2.0 mm s^{-1}, with a 20 mm of penetration distance in the FS. The parameters hardness, adhesiveness, fracture, cohesiveness and elasticity were evaluated (SANCHES, 2010). The measurements were performed with three repetitions.

3 RESULTS AND DISCUSSION

The equation for each response variable can be observed in Table 2. The significant effects are highlighted in bold.

Table 2. Reduced models and adjusted R^2 values for texture parameters.

Parameters	Equations	R^2
Adhesiveness	$\hat{Y} = -0.767 + \mathbf{0.092a} + \mathbf{0.019b} + 0.132c + 0.001ab - 0.003bc$	0.89
Cohesiveness	$\hat{Y} = 1.623 - 0.057a - 0.022b - 0.105c + \mathbf{0.004bc}$	0.72
Toughness	Significant for lack of adjustment	
Elasticity	$\hat{Y} = 15.826 - \mathbf{0.158a} - 0.001b - 0.240c$	0.32
Fracturability	No model was statistically significant	
Gumminess	$\hat{Y} = 0.343 + 0.003a - 0.006b - 0.034c + \mathbf{0.001bc}$	0.38

a = Cassava starch; b = Glycerol and c = Ph

The influence of cassava starch levels and glycerol used in the formulations on the adhesiveness can be observed in the response surface graph of Figure 1a, where pH 6 was kept constant.

Figure 1. Response surface graph for a) adhesiveness, b) cohesiveness, c) elasticity and d) coating gumminess.

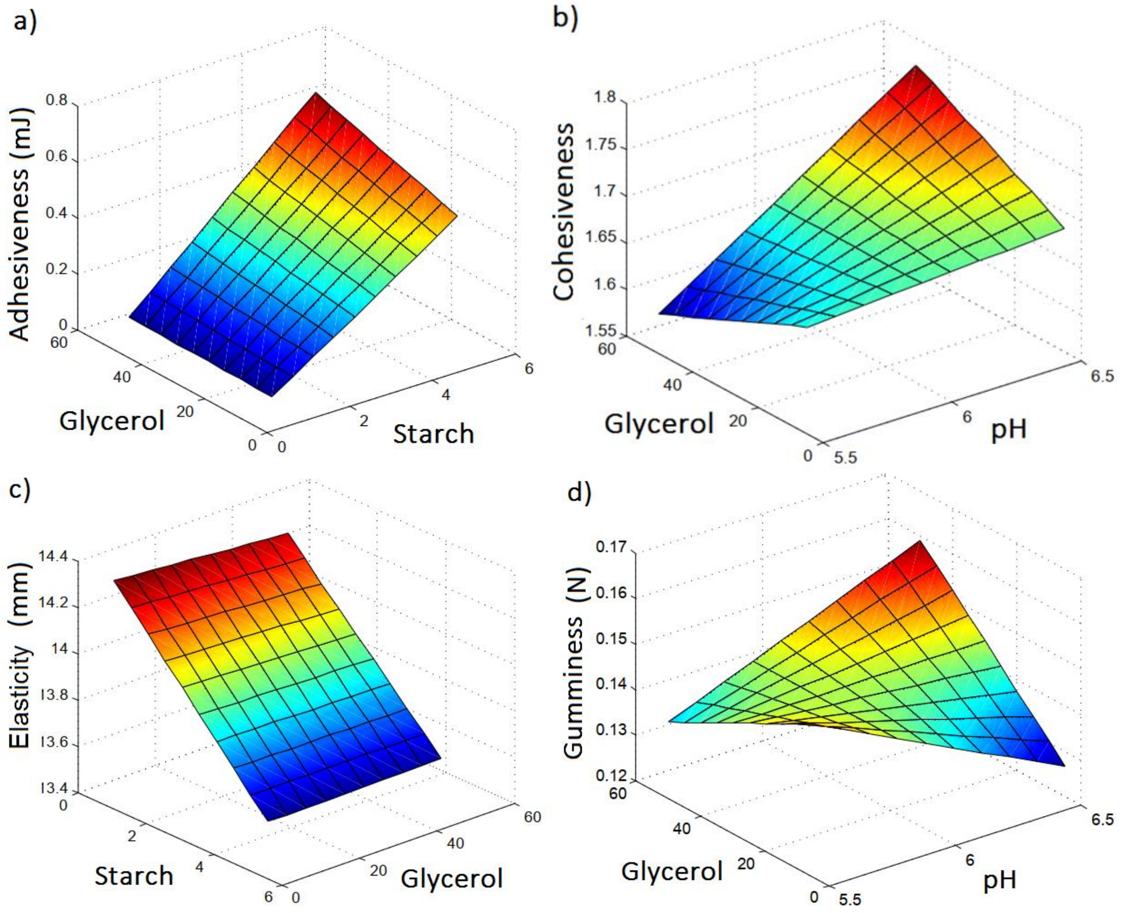

Table 2 shows that adhesiveness is influenced by the contents of cassava starch and glycerol, although there is no interaction between them. The adhesiveness and hardness are characteristics that depend on the cohesive forces, and the viscosity of the gels formed after the gelatinization of the solution. The greater the interaction between the molecules, the greater the resistance, preventing the particles from becoming detached and becoming more adhered to the surface of the seeds. High adhesiveness indicates greater ease of breaking the particles, indicating less hardness, since they are inversely proportional quantities (OLIVEIRA, T. M. et al., 2009).

Cohesiveness (Figure 1b) depends mainly on the interaction between glycerol and pH, whereas the elasticity of the solution (Figure 1c) depends essentially on the starch content. The interactions between amylose molecules are considered important to provide elasticity and resistance to deformation of retrograded starch gels. Inelastic gels break more easily when submitted to compression forces (OLIVEIRA, T. M et al., 2009). According to Weber et al. (2009) cassava starch presents, on average, only 17% amylose. Amylose provides elasticity and greater resistance to retrograded starch solutions, unlike starches with less amylose content which provide more solid gels, with easier penetration and greater stickiness and adhesion. In general, the reduced availability of amylose hinders the establishment of intermolecular forces (hydrogen bonds) over a long distance in the formed gels, resulting in less structure cohesion (WANG & COPELAND, 2013).

The gumminess of the solution (Figure 1d) was dependent on the interaction between pH and glycerol content. Gumminess is dependent on the interaction between hardness and cohesiveness. Gels that are more cohesive have greater strength of internal bonds providing greater resistance to structural rupture, thus presenting greater gumminess (AMARAL et al., 2017).

The knowledge of the filmogenic properties is useful for the developed product to meet the technical needs during the process of seed processing and planting (HALECKY et al., 2016). In addition, the coating formed by adhesive materials must not present resistance to the germination of the seed, allowing the passage of water and oxygen for the embryo development (BRITES et al., 2011).

Leaching of fungicides and other products used in seed treatment is a recurring concern, and seeds treated with polymers provide greater adherence, decreasing the leaching of these products to the environment (AVELAR et al., 2012).

Poor adherence of phytosanitary products during seed treatment can also generate toxic dust formation and the film coating improves stability and adhesion ensuring seed protection, while reducing the environmental impact generated by dust (AVELAR et al., 2012).

4 CONCLUSION

Within the studied range, the variation of the cassava starch, glycerol and pH parameters influenced the adhesiveness, cohesiveness, elasticity and gumminess of the coatings. Since adhesiveness is a fundamental parameter for the adhesion of products to the seed surface, a filmogenic solution containing a higher content of cassava starch is indicated. In the future, it will be necessary to evaluate these factors in relation to the phytotoxicity of coatings on seeds. It is hoped that this work can contribute to the development of biodegradable products containing antimicrobial active substances that will be used in the coating and treatment of seeds.

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REFERENCES

AMARAL, S. A.; OLIVEIRA, J. M.; BURKERT, C. A. V. Perfil de textura de géis de amido adicionados de exopolissacarídeos produzido por bactéria diazotrófica a partir de glicerol residual. XII Congresso Brasileiro de Engenharia Química em Iniciação Científica, UFSCar, São Carlos, SP, v. 1, n. 4, 2017.

ARIENTE, M. et al. Competitiveness in the cassava starch industry: Exploratory. Revista da FAE, v. 8, n. 2, p. 53-60, 2005.

AVELAR, S. A. G. et al. The use of film coating on the performance of treated corn seed. Journal of Seed Science, v. 34, n. 2, p. 186-192, 2012.

BRITES, F. H. R. et al. Germinação de semente comum, escarificada e revestida de diferentes espécies forrageiras tropicais. Bioscience Journal, v. 27, n. 4, p. 629-634, 2011.

CAMPOS, E.V.R. et al. Use of botanical insecticides for sustainable agriculture: Future perspectives. Ecological Indicators, v. 105, p. 483-495, 2018.

CARVALHO, R. S. Método para quantificar CO_2 liberado em frutos infestados com mosca das frutas e tratados com biofilme de amido. Embrapa: Cruz das Almas, BA, Comunicado Técnico, 142, Cruz das Almas, BA, 2010. 6 p.

CHOUHAN, S. et al. Antimicrobial activity of some essential oils—Present status and future perspectives. Medicines, v. 4, n.3, art. nº 58, 2017.

HALECKY, A. et al. Correlation of the mechanical properties of seed coating films and dust-off, flowability, and plantability tests. ASTM International, v. 36, p. 183-201, 2016.
LAMICHHANE, J.R. et al. Revisiting sustainability of fungicide seed treatments for field crops. Plant Disease, v. 104, p. 610–623, 2020.

LIMA, F. R. A. et al. Ethanolic extracts of Momordica charantia L. and Azadirachta indica A. Juss in the physiological and healthy quality of seeds of Moringa oleifera Lam. Brazilian Journal of Development, v. 6, n. 8, p. 60030-60046, 2020.

MACHADO, J. C. et al. Tratamento de sementes no controle de fitopatógenos e pragas. Informe Agropecuário, v. 27, n. 232, p. 76-87, 2006.

MALI, S. et al. Starch films: production, properties and potential of utilization. Semina: Ciências Agrárias v. 31, n. 1, p. 137-156, 2010.

OLIVEIRA, A. F. et al. Preparation, characterization and properties of polymeric films with potential application in seed coatings. Química Nova, v. 32, n. 7, p. 1845-1849, 2009.

OLIVEIRA, T. M. et al. Caracterização do amido de grão-de-bico (Cicer arietinum L.). Boletim do Centro de Pesquisa de Processamento de Alimentos, v. 27, n. 1, p. 27-42, 2009.

PAN, H. et al. Repellency of dimethyl disulfide to Apolygus lucorum (Meyer-Dür) (Hemiptera: Miridae) under laboratory and field conditions. Crop Protection, v. 50, p. 40-45, 2013.

PEREIRA, R. B. et al. Tratamento de sementes de hortaliças. Brasília, DF: Embrapa, Circular Técnica 140, 2015. 16 p.

RAKESH, P. et al. Effect of biopolymers and synthetic seed coating polymers on castor and groundnut seed. International Journal of Pure & Applied Bioscience, v. 5, n. 4, p. 2043-2048, 2017.

SANCHES, M. F. Caracterização física de soluções de inulina e FOS por análise de textura e comportamento reológico. 2010. 100f. Dissertação (Mestrado em Engenharia química) - Universidade Federal de santa Catarina, Florianópolis, SC, 2010.

SARANGAPANI, C. et al. Atmospheric cold plasma dissipation efficiency of agrochemicals on blueberries. Innovative Food Science and Emerging Technologies, v. 44, p. 235-241, 2017.

SCHOENINGER, V., BISCHOFF, T. Z. Tratamento de sementes. Journal of Agronomic Sciences, v. 3, n. especial, p. 63-73, 2014.

SHARIF, M. et al. Detection and classification of citrus diseases in agriculture based on optimized weighted segmentation and feature selection. Computers and Electronics in Agriculture, v. 150, p. 220-234, 2018.

VERSINO, F. et al. Starch-based films and food coatings: An overview. Starch-Starke, v. 68, n. 11-12, p. 1026-1037, 2016.

WANG, S.; COPELAND, L. Molecular disassembly of starch granules during gelatinization and its effect on starch digestibility: A review. Food &Function, v. 4, n.11, p. 1564-1580, 2013.

WAQUIL, J. M. et al. Manejo Integrado de Pragas (MIP). Embrapa, 2005. Disponível em: < https://www.agencia.cnptia.embrapa.br/Repositorio/AG01_70_16820051120.html>. Acesso em: 17 nov. 2020.

WEBER, F. H.; COLLARES-QUEIROZ, F. P.; CHANG, Y. K. Caracterização físico-química, reológica, morfológica e térmica dos amidos de milho normal, ceroso e com alto teor de amilose. Ciência e Tecnologia de Alimentos, v. 29, n. 4, p. 748-753, 2009.