Ex-vivo mechanical characterization of the mucous in bovine tongue tissue

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Introduction

Soft tissues coat, bind and join different elements of the body. From a mechanical point of view, most soft tissues conform to nonlinear stress-strain behavior [1]. The tongue is one of the most amazing soft tissues because it has an essential role in most biotic operations such as breathing, speaking, manipulating, and swallowing food.

Biomechanical modeling of the human tongue requires recognition of its mechanical properties which govern its behavior. The musculatures of the tongue between humans and bovines are similar. This is probably less true for the mucous membrane, which has in bovine nutrition a functional role that does not exist in humans. However, studying the bovine tongue remains an interesting framework to estimate general key characteristics of tongues. In this research, the mechanical properties of the bovine mucous membrane were studied experimentally via uniaxial and biaxial tensile tests.

Methods

Five fresh bovine tongues were collected after the sacrifice, from the slaughterhouse. The tongues were immersed in a zero-degree saline dilution to be carried for uniaxial and biaxial tensile tests. For uniaxial tensile tests, some rectangular samples were obtained with a width-to-length ratio as close to 1:3 (as required by the ASTM standard [2]).

For biaxial tensile tests, cruciform specimens were prepared that were sliced with a surgical blade (figure).

Square areas in the center of cruciform specimens were measured to compute stress and strain values.

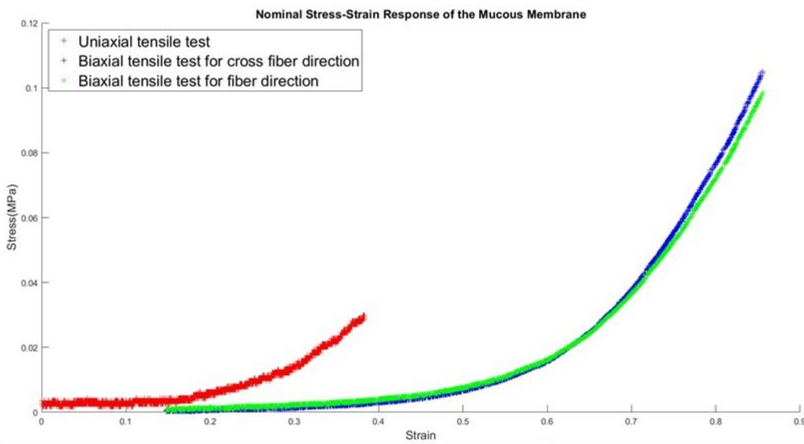
All tests were done with different strain rates to measure viscoelastic properties as well.

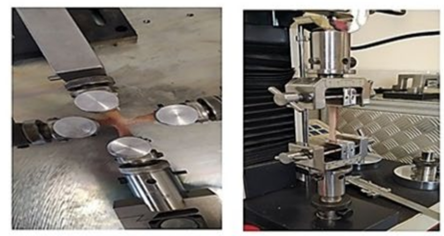
Results

Various hyperelastic constitutive laws proposed in the literature for modeling soft tissues were compared to fit the collected experimental data. For this purpose, the parameters of these constitutive models were estimated using both uniaxial and biaxial data at the same time. As an accepted hypothesis for living soft tissues, full incompressibility was considered. Also because of mucous membrane structure, the assumption of isotropy was supported between different specimens which were cut along different directions. The results indicate that the 3rd order Ogden model, 2nd order polynomial model, and Yeoh model are most appropriate. The Ogden model provided the most accurate fit, and from its strain energy density function, the relevant parameters are given in table (figure).

Discussion

The assumption of full incompressibility is idealistic and needs to be verified through the appropriate measurements. The mucous membrane does not show a fibrous structure but it seems that it has a layered one with different properties. This layered structure needs to be studied carefully to have a realistic rheological model especially when the frictional behavior of its fuzzy lint plays a role.





	Type of behavior	Isotropy	Constitutive model	Coefficients of strain energy density function		
Mucous Membrane	Hyperelastic	Isotropic	Ogden model (N=3)	μ_1(MPa)	μ_2(MPa)	μ_3(MPa)
				6.05	5.52	-5.49
				α_1	α_2	α_3
				3.45	10.05	-3.94

Uniaxial and biaxial results with model parameters for bovine mucous membrane.

References

[1] Ali-Akbar Karkhaneh Yousefi, Mohammad Ali Nazari, Pascal Perrier, Masoud Shariat Panahi, Yohan Payan, 2018. A new model of passive muscle tissue integrating Collagen Fibers: Consequences for muscle behavior analysis, Journal of the Mechanical Behavior of Biomedical Materials. 88, 29-40

[2] ASTM D638 – 14, Tensile Properties of Plastics Standard Test Method.