Novel Rice Gel for Ultrasound Applications: Physical and Chemical Properties

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Abstract:

Background: Ultrasound gel is a medical device that belongs to the category of consumables, which included in charge of radiological diagnosis and treatment such as X-ray, CT scan, ultrasonography, MRI, radionuclide scan and various radiotherapy, etc. This material is a pharmaceutical product, which produced in a gel state and obtained from synthesized for medical or veterinary. For example, physical examination acts a coupling agent between the body and the medical device. This gel is a product that must be imported from abroad at the level of billions of baht every year.

Objective: This research fabricated medical ultrasound gel within the country. The main raw material was being Thai rice to solve the problem of importing ultrasound gel from abroad.

Materials and Method: Novel rice gels containing different compositions of rice starch (RS) powder and additives. The formulations of gels were composed of RS powder, liquid glycerol, and additives by solution method. Five solutions with different concentration of RS powder (0.5 g, 1 g, 1.5 g, 2 g and 2.5 g) were prepared by solution method. These solutions were dried in electric oven at 65^{O}C for 4 hours. The physical and chemical properties of rice gel characterized by turbidity, viscosity, smell, irritation, pH and moisture content of these gels have monitored.

Results: Results showed that 2 g of RS powder is optimized formulation which had turbidity, high viscosity, pleasant smell, non-irritating and easy to clean. The pH value of this gel was 6.92 ± 0.01, and the moisture content was 0.21 ± 0.07 %, which similar to commercial standard of ultrasound gel (UG).

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Conclusion: These results concluded that the application of RS in gel ultrasound was safe and effective for replacement commercial gel ultrasound. This gel should be studied on image quality in ultrasound examination for next step.

Keywords: Ultrasound, Gelatinization, Rice starch, irritation, Ultrasound gel, Water soluble

Introduction

Ultrasound is the mechanical waves those frequencies above 20,000 Hz and beyond the audible range of sound. In ultrasound therapies through the 1930s were used to therapeutic applications such as cancer treatments, pregnant and physical therapy for various diseases. Diagnostic applications of ultrasound began in the late 1940s through cooperation between physicians and engineers experience with SONAR.[1] Ultrasound waves have frequencies between 1 to 20 MHz. The physical and chemical properties of the UG were the significant factor relate to image quality. In biological tissues, ultrasonic energy was spread mainly form of longitudinal waves while it moves in media.[2] UG shall be good acoustic contact between the transducer and the skin.[3] UG used be general include water, various oils, creams and gels. Commercial standard UG are a water soluble, hypoallergenic, non-toxicity, sterile, pH = 6.5 ± 0.75, density = 0.983 g/cm^3, translucent screen with high viscosity, etc.[4] In present, the disadvantages of UG are dissolving of rubber or plastic parts of the transducer[3], expensive[5], irritation[6] and use in large quantity for each examination. Thus, this research has idea for used hydrogels that mainly liquid in composition and display densities similar to aqueous. The network of gel can be composed of a variety of polymers. Polysaccharides are natural polymers which hydrophilic, biodegradable, biocompatible and gelling agent.[7]

Starch is one of a food energy resource in the world. In addition, it is used by the food industry in a broad range of products because of its gelling, thickening and food system stabilizing capacity. Gelling property modified by chemical modifications such as cross-linking and substitution can increase the resistance to shear, acid and high temperatures, reduce retrogradation and improve freeze thaw stability and heat treatment. Besides physical modifications, mixing different additives and plasticizer is another way to obtain new starch properties because of its low cost, nontoxic and innovative.[8] In 2017, Thailand was the number one of rice exporter in the world, followed by India and Vietnam. Thailand produced 480 million tons of unmilled rice in countries, and exports 9.7 million tons of rice.[9] However, rice is contributed only 23% of the total exports value. Therefore, more researches on rice aiming at improving its value are urgently needed. Rice starch (RS) is extensively used in pharmaceutical and biomedical applications. It is produced by Erawan Pharmaceutical Research and Laboratory Co., Ltd., Thailand.[10] This research aimed to study physical and chemical properties of commercial standard ultrasound media and RS gel for basic knowledge to development image quality in ultrasound examination.

Materials and Methods

Sample preparation

6 ml of Glycerol solution (Sigma-Aldrich, 99.5%, United State Pharmacopeia (USP), Thailand) was blended in 5 ml distilled water and added to 1 g of sucrose (Sigma-Aldrich, 99.5% USP, Thailand) to solution and then heated to 80°C. The mixture

stirred for 15 min. Then, 0.02 g of sodium hydroxide (Fluka, 98%, analytical grade, German) dissolved in 20 ml of distilled water, and heated to 85°C (the optimal gelatinization of RS occurs at 85-90°C). Then the RS powder added 0.5, 1, 1.5, 2 and 2.5 g and added 0.32 g of carboxyl methylcellulose (Sigma-Aldrich, 99.5% USP, Thailand). The obtained mixture was stirred for 20 min until homogeneous. Once both solutions prepared, the mixture was blended in homogeneously paste at room temperature for 30 min in a beaker on a hotplate and stirrer until the RS gel produced. Then, neutralization of the RS gel with pH = 7. The RS gel mixed 0.02 g of methyl paraben (Sigma-Aldrich, reagent grade, 95%, Thailand), and then the gel was stirred for 10 min until mixed well. The prepared RS gels took in dried oven 65°C for 4 hour.

Characterization

pH values

The determination of pH values of the samples were carried out using a waterproof pH spear tester (Oakton pH Spear Water proof Pocket Tester EW-35634-40-Pro, Singapore). Measured ranges were from -1 to 15, with a resolution of 0.01, and accuracy was ±0.01. Measurement of temperatures ranged from 0 to 50 °C. Before measurements, the probe was rinsed with de-ionized water before insertion into the body of the samples. After the measurement, it was rinsed with deionized water and immersed in a buffer solution. All samples were measured five times, and data was collected for average values.

Moisture content

The determination of the moisture content was done by using a moisture analyzer (PMB 53, ADAM, Singapore). The samples were prepared by weighing approximately 1 to 2 g, with a resolution of 0.01% and sensitivity of 0.1 mg, and placed on a pan at 0-50˚C for 4 min. Each sample was tested five times, and data was collected to determine the average values.

Viscosity analysis

Viscosity properties of the samples were studied, using a suspension viscometer (DV-III+, Brookfield), needle No. 29, temperature 31-35°C, and speed +20 rpm up to 9 points. Viscosity model was measured by the following equation: $\sigma = \sigma_0 + \eta_B\dot{\gamma}$ where σ is shear stress, σ_0 is the yield stress, η_B is the plastic viscosity of the samples, and $\dot{\gamma}$ is shear rate. All measurements were repeated five times and the mean value was taken.

Appearance evaluation

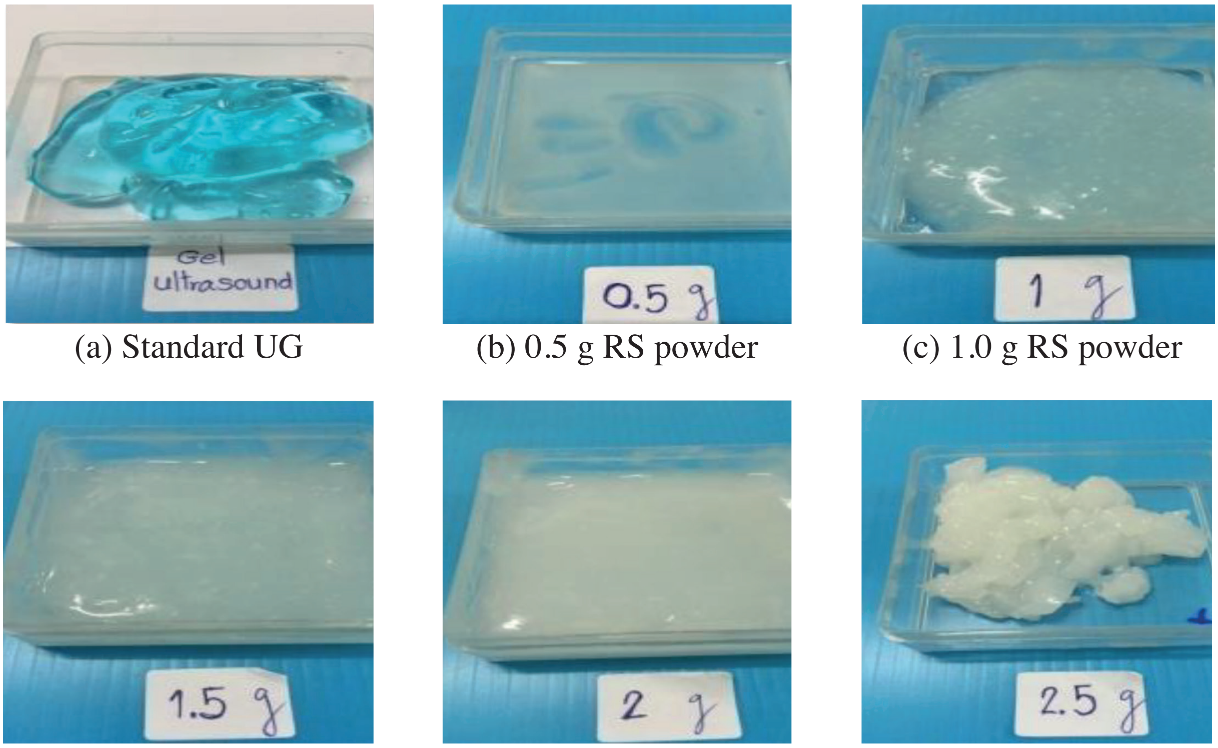
To observed the appearance of rice gel by the five senses of volunteers. For examples, turbidity, smell, and skin irradiation. Skin irritation test by 1. Evaluate according to the pH value of rice gel. 2. Applying the gel on the skin of 30 volunteers who were not real patients and leaving it for 15 minutes, then observe the changes in the skin, whether there is a rash, itching or not.

Statistical analysis

All quantitative data were analyzed with origin 8.0 (OriginLab Corporation, USA) and presented as the mean ± standard deviation. Statistical comparisons were carried out using analysis of variance (ANOVA, Origin 8.0). A value of $p < 0.05$ was considered to be statistically significant.

Results and Discussion

Figure 1 shows the various compositions of ultrasonic media that form by starch-based matrix and hot air oven with gelatinized temperature 85-90°C as gelling agent and the other additives for increased viscosity, plasticizer, stability and preservative agent. All formulations with different addition of RS powder ranging 0.5 g to 2.5 g showed physical and chemical properties and standard UG (Table 1). These results demonstrate that all formulations had turbid more than standard UG except an addition 0.5 g of RS powder in composition due to small content of RS powder (Figure 1b). However, the addition 0.5 g RS powder show viscosity lower than standard UM. Thus, no appropriate use as gel ultrasound. Moreover, the additions of 1 and 1.5 g of RS powder showed that the viscosity lower than standard UG too (Figure 1c and Figure 1d). On the other hand, an addition of 2 g of RS powder (Figure 1e) had the viscosity equivalent standard UG that should be appropriate as ultrasound gel. This due to the viscosity of rice gel was non newtonian gel. While 2.5 g RS powder in composition showed the viscosity higher than standard UG, due to gel became hard jelly (Figure 1f). Thus, no appropriated used as gel ultrasound.



(a) Standard UG (b) 0.5 g RS powder (c) 1.0 g RS powder

(d) 1.5 g RS powder (e) 2.0 g RS powder (f) 2.5 g RS powder

Figure 1 Appearance of comercial standard UG (a), and rice gel at various contents (b) to (f)

All formulations had a pleasant smell, non-irritating when used for skin application, and were easy to clean. They are starch-based gels containing similar compositions that follow their use in ultrasonic applications.

Table 1 Physical and chemical properties of UG derived from standard UG and RS gel

Type	Turbidity	Viscosity (mPa.s)	Smell	irritation	pH	Moisture content (%)
Standard UG	transparent	1966 ± 96	pleasant smell	non irritating	7.14 ± 0.02	0.59 ± 0.04
0.5 g RS	quite transparent	789 ± 2	pleasant smell	non irritating	6.97 ± 0.13	0.34 ± 0.16
1.0 g RS	turbid	354 ± 2	pleasant smell	non irritating	7.03 ± 0.03	0.45 ± 0.04
1.5 g RS	turbid	1479 ± 51	pleasant smell	non irritating	6.90 ± 0.01	0.37 ± 0.11
2.0 g RS	turbid	1898 ± 15	pleasant smell	non irritating	6.92 ± 0.01	0.21 ± 0.07
2.5 g RS	turbid	2865 ± 8	pleasant smell	non irritating	6.95 ± 0.11	0.46 ± 0.17

Data showed pH values were ranged from 6.90 to 7.14, which occur in all formulations, and moisture content showed that all formulations below 0.6%, which was water activity of food that pathogenic or spoilage microorganisms cannot grow.[11] This phenomenon explained by influence of RS powder in compositions occurred from gelatinization of RS powder by base and thermal treatment. RS powder should adequately modified by destroying by its granule. When heated in the presence of water, RS undergoes an irreversible structure. RS powder had swelling pattern, which occurred internal bonding of each granules. Gelatinization optimizes results in the formation of a viscous paste with disorder of between molecular hydrogen bonds. This bonding derived from crystal and amorphous of rice starch, which had low solubility and swelling properties. These were due to both of amylose and amylopectin of RS that amylose made strength of RS structure.[12,13] Thus, transparency and viscosity of rice gel must be through gelatinizing process and mixed other additives. In this research, carboxyl methylcellulose used as emulsifier for stability increased thickener for starch gel[14], and sucrose used as additive for binder[15], water used as plasticizer. The addition of the other plasticizer was a glycerol for increasing water solubility because of glycerin would blend and bond with molecule of RS. Glycerol molecule occurred physical cross linked with neighbor site chain of RS molecules as weak interaction form molecular was structure flexible.[16] Methylparaben was preservative that inhibited the growth of bacteria.

Conclusion

Novel rice gels for ultrasound were modified by base and thermal treatment methods with different compositions of RS powder. The influence of the addition RS powder had an important effect on turbidity, viscosity, smell, irritation, and cleaning. For the addition of RS powder the concentrations from 0.5 to 2.5 g in formulation. The optimized formulation was 2 g of RS powder added in composition which was about 74 wt% of constituent. This concentration showed appropriate formulation as turbid, high viscosity, pleasant smell, non-irritating, easy to clean, water-soluble and low cost. This research should be further studied on image quality in ultrasound examination.

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