Journal of the Korean Nuclear Society
Volume 8, Number 3, September, 1976

Alterations in the Properties of Agar by Ionizing Radiation

Su-Rae Lee, Sang-Ki Park and Han-Ok Cho*

Korea Atomic Energy Research Institute, Seoul

(Received June 1, 1976)

Abstract

Alkali-treated red algae, *Gracilaria* sp. was irradiated with various doses of cobalt-60 gamma-rays and the yeild and properties of agar extracted from the seaweed were examined and compared with the quality of commercial agar powder after irradiation.

Extraction yield of agar from irradiated seaweed was proportionally increased as the radiation dose was raised up to 2 Mrad whereas it tended to decrease slightly thereafter. Gelation ability, gelation point, gel hardness and specific viscosity of the agar were increased up to 1 Mrad and decreased at higher dose levels while its melting point, total nitrogen, crude ash and total sulfur decreased up to 1 Mrad level and remained unchanged thereafter.

Irradiation of commercial agar powder caused remarkable decreases in the gelation ability, specific viscosity and gel hardness and slight decreases in the gelation point and melting point. The pattern of alterations in the properties of agar samples differed whether the polysaccharide was irradiated in free state or bound state in seaweed.

요 약

한천 原藻인 꼬시레기를 여러가지 선량의 코발트 60 감마선으로 照射하고 이에서 추출한 한천의 수율 및 특성을 조사하였으며 방사선조사한 한천분말의 품질과 비교하였다.

방사선조사한 原藻에서의 한천의 수율은 조사선량이 2 Mrad 까지 상승됨에 따라 증가하였고 그 이상에서는 약간 감소하는 경향이었다. 한천의 겔화능력, 겔화점, 겔견고성 및 비점도는 1 Mrad 까지 증가하였고 그이상에서는 감소하였으며 융점, 전질소, 조회분, 전유황 함량은 1 Mard 까지 감소하였고 그 이상에서는 변화가 완만하였다.

시판용 한천분말의 방사선조사는 겔화능력, 비점도, 겔견고성의 급격한 감소와 겔화점, 융점의 완만한 감소를 가져왔다. 한천시료의 특성의 변화패턴은 한천을 유리상태 또는 결합상태(海藻중 존재형태)에서 照射하는가에 따라 달리 나타났다.

* Present Address: Department of Food and Nutrition, Soodo Women's University, Seoul

1. Introduction

Early studies on the treatment of food materials with ionizing radiation have mainly concerned with the aspects of their preservation. During the course of these studies, it became, however, apparent that significant improvements in technological quality may occur from the application of radiation to food materials[1]. For instance, irradiation of high molecular carbohydrates like starch, cellulose and pectins causes alterations of some of their physical properties which are connected with the radiation-induced depolymerization of the chain molecules and can help to improve their technological processing.

Algal polysaccharides like agar and algin ate are seaweed products of significant economic importance in Korea because of the abundant supply of raw seaweeds and of their increasing demands in industrial fields such as food, fiber, paper, drug, cosmetics and waste treatment. Studies on the effects of radiation on algal polysaccharides and seaweeds were reported by a few workers[2-4] and it was suggested that the extraction yield of agar from raw seaweeds could be raised by gamma-irradiation.

This study was, therefore, undertaken to investigate the effects of gamma-rays on the extraction yield and quality attributes of agar from irradiated seaweed in comparison with the alterations of physical properties of commercial agar powder by the radiation.

2. Experiments

1) Seaweeds and commercial agar powder

Alkali-treated red algae, *Gracilaria* species imported from Manila was thoroughly washed with tap water to remove impurities, dried and cut into 2-3 cm dimension for agar extraction (moisture content: 17%). Commericial agar powder was a reagent grade product from GBI Co., USA, Lot No. 83279(moisture content: 11%).

2) Irradiation

Dried seaweed and commercial agar powder packed in polyethylene bag were irradiated at room temperature with different doses of gamma-rays at average dose rate of 1 Mrad/hr by means of BNL's shipboard irradiator (20,000Ci ^{60}CO) installed at this Institute.

3) Extraction of agar

Twenty grams of seaweed were heated with 1 liter of tap water in an autoclave at 15 lbs pressure for 45 minutes. The extracts, while hot, were filtered through cotton cloth by means of Carver Laboratory press(Model C) and allowed to form gel by cooling to room temperature. The gel was stood for 3 hours at −7°C and then frozen for 20 hours at −15°C. The frozen gel was allowed to thaw and the dehydrated agar residue was subjected to dissolution by heating, gelation, freezing, thawing and dehydration. The freezing-and-thawing procedure was repeated twice more and agar powder was obtained after drying and grinding. The percent yield of air-dried agar was calculated on the basis of washed, dry seaweed for five repeated runs. The error for the yield test was about ±20%.

4) Chemical analyses

Total nitrogen and crude ash were analyzed by conventional methods[5] and total sulfur, by colorimetric method after distillation[6].

5) Assessment of physical properties

Gelation point and gelation ability of agar

samples were determined according to a previous paper[4]. Viscosity of agar solution in water(0.3% concentration) was measured at 40°C by use of Ostwald viscometer and expressed as specific viscosity against distilled water. Melting point of agar gel was determined according to Hayashi & Nagata[7]. Texture of agar gel was recorded by General Foods Texturometer according to a previous report[4] and hardness thereof was regarded as representing jelly strength of the agar gel.

3. Results and Discussion

1) Extraction yield of agar from γ-irradiated seaweed

Agar was extracted from γ-irradiated seaweed and its yield was examined to obtain the results as shown in Fig. 1. The yield

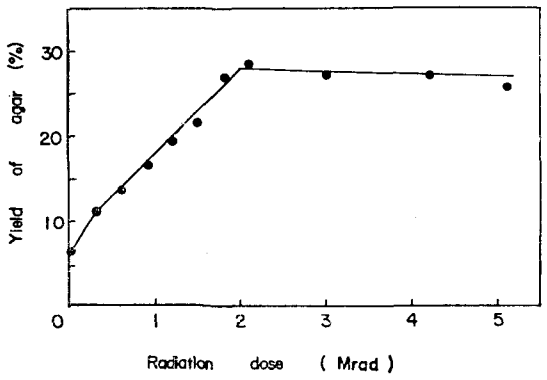

Fig. 1. Effect of γ-irradiation on the extraction yield of agar from Manila seaweed, *Gracilaria* sp.

was proportionally increased as the radiation dose was raised up to 2 Mrad whereas it tened to decrease slightly thereafter. The mechanism of yield increase by ionizing radiation is not fully explained whether it is due to the rupture of algal cell wall or modification of agar molecules for easy penetration through the cell wall. The slightly lowered yield at the higher radiation doses is likely due to the decomposition of agar molecules to bring about the loss of gelation capacity.

2) Quality characteristics of agar from γ-irradiated seaweed

Physical and chemical properties of agar samples according to the dose of ionizing radiation as applied to the raw material seaweed are shown in Figs. 2, 3 and 4.

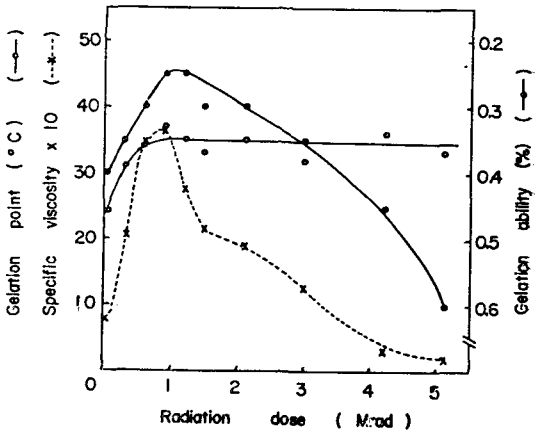

Fig. 2. Physical properties of agar samples extracted from γ-irradiated seaweed.

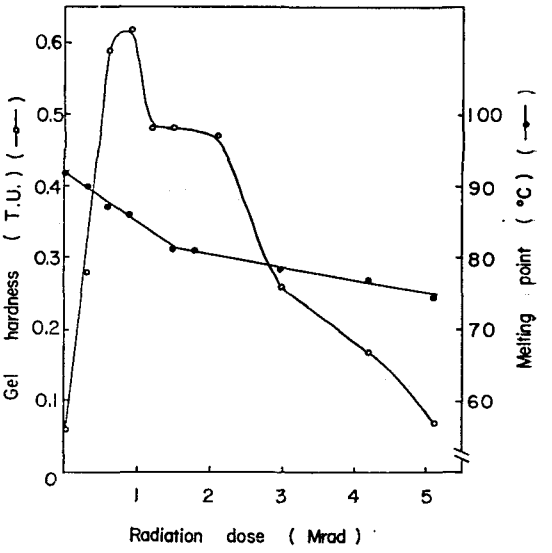

Fig. 3. Hardness and melting point of gels from agar samples extracted from γ-irradiated seaweed.

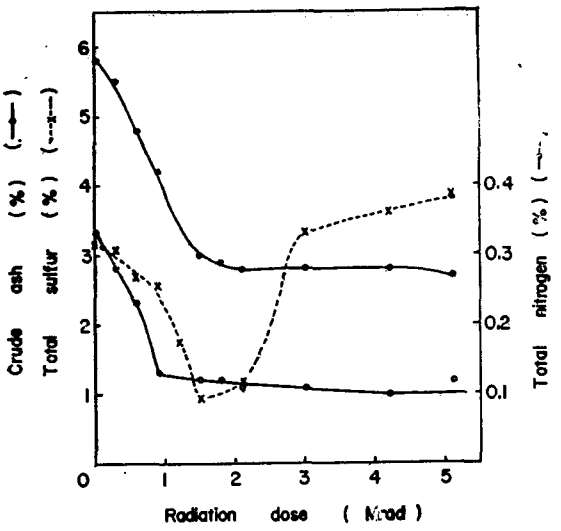

Fig. 4. Chemical properties of agar samples extracted from γ-irradiated seaweed.

The gelation ability and specific viscosity of agar solution were increased up to 1 Mrad dose level and decreased at higher dose levels. Gelation point was elevated by 1 Mrad dose level and remained constant therafter. Specific viscosity of polymers should be related to the degree of polymerization and this property was well reflected in the gelation ability. The texture of agar gel was also affected by ionizing radiation and particularly the gel hardness which is supposed to have a high correlation with jelly strength of gels[8] showed the similar behavior with the specific viscosity of agar solution. Melting point of the agar gel was decreased as the radiation dose was raised, showing a bending point at 1.5 Mrad dose level.

Chemical properties of agar samples were also altered by irradiating the seaweed. Thus the total nitrogen and crude ash of agar samples were markedly decreased up to 1 Mrad dose level and remained unchanged thereafter. However, the changes in total sulfur content showed a V-shaped pattern, the lowest being at 1.5 Mrad level. These changes in chemical properties of agar samples by γ-rays can not be directly correlated with alterations of physical properties of the product, though it was known[9] that the gelation ability, the most important quality attribute of algal polysaccharides depends on the molecular weight, sugar composition and ionizable groups of the molecules.

Nevertheless, it should be noted that the radiation doses up to 1 Mrad brought about remarkable alterations both in the physical and chemical properties of agar samples toward better technological quality and higher doses caused the reverse or minor effects in the properties. Therefore, the application of ionizing radiation to seaweeds at a properly chosen dose level should be made available very efficiently to improve the extraction yield and technological quality whatever the exact mechanism of alterations in the properties may be.

3) Physical properties of commercial agar after γ-irradiation

Changes in the physical properties of commercial agar powder according to the dose of ionizing radiation are shown in Figs. 5 and 6.

The gelation ability, specific viscosity and gel hardness of agar solution were remarkably decreased as the dose level was raised. Since these properties are closely related to the degree of polymerization, it is assumed that the agar polymer should have been degraded by the ionizing radiation.. The gelation point of agar solution and melting point of agar gel were also gradually decreased as the dose level was raised, showing bending points at 1 and 2 Mrad levels, respectively.

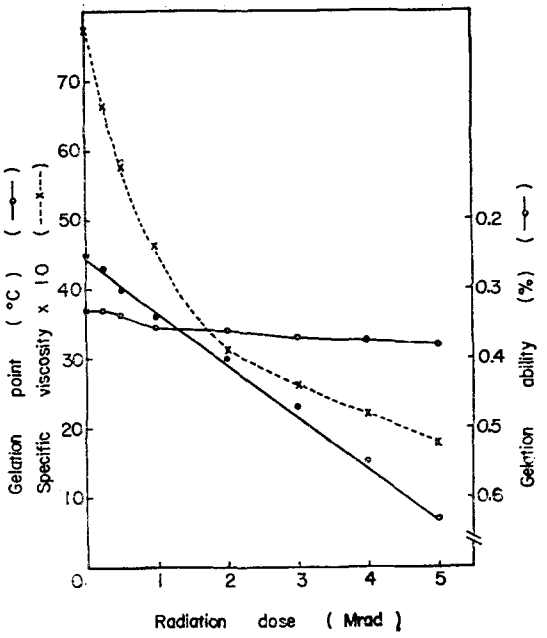

Fig. 5. Effect of γ-irradiation on the physical properties of commercial agar powder.

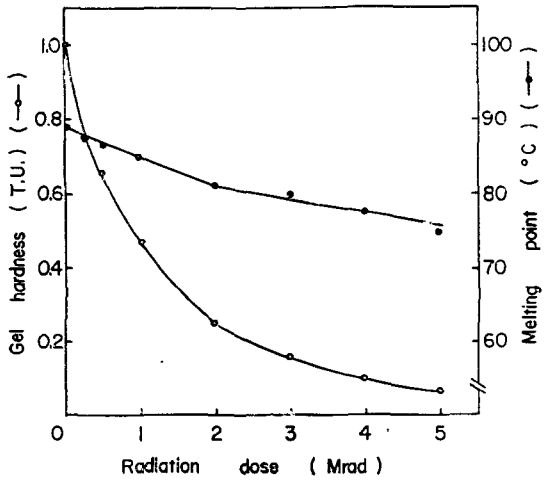

Fig. 6. Effect of γ-irradiation on the hardness and melting point of gels from commercial agar powder.

As it is known that irradiation of high molecular carbohydrates like starch, cellulose and pectins causes alterations of their physical properties like viscosity, mechanical strength, swelling and solubility, due to the radiation-induced depolymerization of the chain molecules[10], it is clear that agar molecules should have undergone these types of alterations by γ-irradiation. A noticeable difference was, however, observed in the alterations of physical properties of agar whether it was irradiated in pure state or in natural state of the seaweed. That is, all tested physical properties of agar samples extracted from irradiated seaweed showed the reverse effect at dose levels below 1 Mrad suggesting that agar molecules in bound state in nature were not subjected to radiation-induced depolymerization at such low dose levels. Only if such low doses can bring about minor modifications for the agar molecules themselves or for the interaction between agar molecules and algal cell components, causing the liberation or extraction of agar from the seaweed very easy, the application of irradiation in agar extraction processes should become quite possible. The increase in the extraction yield of agar from γ-irradiated Manila seaweed, *Gracilaria* sp. as demonstrated in this study will suffice to support the possibility of practical application of ionizing radiation in agar industry.

References

1) IAEA, Improvement of Food Quality by Irradiation, IAEA, Vienna, STI/PUB/370, 188 p. (1974).
2) K. Kazuura, S. Suzuki and T. Okano., J. Ind. Chem. (Japan), **65**, 1076 (1962).
3) Y. A. Doshi, S. T. Talreja and R. P. Srinivasa, Indian J. Technol., **6**, 275 (1968).
4) H. O. Cho and S. R. Lee, Korean J. Food Sci. Technol., **6**, 36 (1974).
5) Kyoto University, Laboratory Manual in Food Technology, Yokendo, Tokyo. Vol. 1, p. 537-542 (1970).

6) L. Gustafsson, : Talanta, **4**, 227 & 237 (1960).
7) K. Hayashi and Y. Nagata, J. Food Sci. Technol. (Tokyo), **14**, 450 (1967).
8) T. Matsuhashi and K. Hayashi, Agr. Biol. Chem. (Tokyo), **36**, 1543 (1972).
9) T. Fuse, J. Agr. Chem. Soc. Japan, **43**, 110 (1969).
10) H. Scherz, Improvement of Food Quality by Irradiation, IAEA, Vienna, p. 39 (1974).