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Can Eun Bo's Silver Chopsticks Really Detect Poisons?

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Abstract
The Korean drama, *Queen: Love and War*, is set in the Joseon era of Korea, and stars Eun Bo; after the death of her sister, she enters the selection to become the new queen so that she has the power to find who killed her sister. As the final selection task, she and the other girls are asked what they would sacrifice to become the queen, and she volunteers her silver cutlery that she claims can detect poison. This paper explores this idea by identifying potential poisons that Eun Bo could have been faced with, and evaluating whether silver cutlery could detect them effectively.

Keywords: *KDrama; Biology; Chemistry; Poisons; Detection; Queen: Love and War; Silver*

In episode 9 of the Korean drama *Queen: Love and War*, the main character and queen hopeful Eun Bo, along with the other contestants competing to be the queen, are asked to select something that they would be willing to sacrifice in order to achieve the position [1]. While the other competitors choose to sacrifice shoes and even their past, Eun Bo offers up her silver cutlery, saying "Silver spoons are used to detect poison" [1]. This article will explore whether Eun Bo is right in her conclusion, and whether, in the Joseon era of Korea, silver cutlery could be used by the aristocracy to detect poisons.

Possible Poisons in the Kingdom of Joseon

The Kingdom of Joseon lasted from 1392 – 1910, and the area covers all of the Korean peninsula: modern North and South Korea [2]. The main trade was with China, by land, and Japan, at the island of Tsushima [2]. With the Joseon Kingdom being on a peninsula, any poisons or toxins would have to have been found locally or brought in along these main trade routes. One well documented poison is arsenic, which can be found in soils from China, and can be produced as a result of mining, smelting processes, or wood burning [3]. Arsenic levels can also rise in groundwater when sewage disposal is inadequate [3]. Furthermore, certain foods can also accumulate arsenic and act as an exposure source, particularly: cereals, grains, fish, prawns, and crabs [3]. Agriculture was the main industry of the Kingdom of Joseon, and the staple crop was rice, with barely, millet, and soybeans as additional crops [2]. All the grains, rice barely and millet, can accumulate arsenic, leading to arsenic poisoning. Arsenic reacts with sulphur containing enzymes in the body [4] and, although arsenic poisoning has no specific symptoms, it has been associated with: weariness, loss of reflexes, weight loss, anorexia, hair loss, cardiovascular diseases, circulatory diseases, and kidney and liver disorders [3].

Arsenite, which is an arsenic containing compound, can lead to reduced protein expression in the mitochondrial superoxide dismutase (SOD), overall resulting in the activities becoming downregulated [3]. This, over time, can produce toxic effects through the build up of reactive oxygen species and free radicals. The overproduction of these can damage mitochondria and lead to mutations in the mitochondrial DNA [5]. This interferes with three of the four complexes in the electron transport chain, which allow for oxidative respiration and large amounts of energy to comparatively be produced from glucose [3].

Another possible poison that could have been present in the Kingdom of Joseon is abrin. Similar to the known poison ricin, abrin is a phytotoxin that is isolated from the plant *Abrus pecatorius*, which is native to multiple countries, including China [6].

When added to food or water as a contaminant, the toxin is moved into the cell and blocks translation, leading to severe abdominal pain, vomiting, diarrhoea, kidney failure, and bleeding in the gastrointestinal tract, with death occurring between 36 and 72 hours after exposure [6]. When inhaled, abrin can result in hypertension of the pulmonary arteries, and lysis of red blood cells [6]. Abrin can also induce apoptosis as the A chain of the protein has the activity of an RNA N-glycosidase, which allows it to be endocytosed more easily into cells [7]. Once there, abrin can inhibit protein synthesis and has also been connected with the loss of the mitochondrial membrane potential, which is required for oxidative phosphorylation and respiration [7]. Abrin is also a very strong toxin, with the LD_{50}, the lethal dose for 50% of the population, being 0.04 μg/kg of body weight in mice; in humans, the estimated fatal dose is 0.1 – 1 μg/kg [6, 7]. Toxins from other sources, like the pathogen produced botulinum toxin [6], whilst known about in the present day, would not have been easily isolated throughout most of the Joseon era, and so are not as applicable or relevant for Eun Bo to need to detect.

Detection of arsenic containing compounds

In Baekje, one of the early three kingdoms of Korea, silver chopsticks were believed to be able to detect arsenic in food through a colour change long before the Joseon era [4]. As arsenic is often found in sulphides naturally, the sulphides react with silver in the reaction shown below, leading to a colour change as black silver sulphide is produced which, in the equation below, is Ag_2S [4].

$$6\ Ag + As_2S_3 \rightleftharpoons 3Ag_2S + 2As$$

The Ag_2S product is seen as black and is now referred to as the metal tarnishing [4]. Silver ions in solution can also be used to detect arsenic when in the oxidation state +3, and in the arsenite ion; in the precipitation reaction, a solid product is formed from two aqueous reactants. The equation for this reaction is:

$$3Ag^{+}_{(aq)} + AsO_3^{3-}{}_{(aq)} \rightleftharpoons Ag_3AsO_{3(s)}$$

The problem with attempting to detect arsenic with solid silver is that it has to be in a sulphide compound, and it cannot be detected in other forms [4]. Furthermore, to detect the arsenite ion, silver(I) ions in solution are required, which would have been more difficult to acquire in the Joseon era and cannot be gained for use directly in solid cutlery. Natural sulphides exist in foods and also lead to tarnishing which, as well as giving a false result, would take time to develop a visible reaction result [4]. Furthermore, arsenic poisoning, unless given in high doses, is associated with diseases like cancer rather than quick fatalities [3], and so would be unlikely to be the poison of choice for someone hoping to remove Eun Bo, or another royal, quickly.

Detection of abrin

Abrin cannot be detected through reactions with silver, and so silver cutlery would not help to protect or alert Eun Bo to the poison. Furthermore, gold nanoparticles can be used to detect abrin in conjunction with surface enhanced Raman scattering, however this technology would not be applicable to the Joseon era [7]. Affibodies, high affinity and high stability small proteins, with electrochemiluminescence machinery can also be used to detect abrin poison but faces a similar problem of the time period and the available technology [8]. It is unlikely that any technology in the Joseon era could directly detect abrin.

Conclusion

While Eun Bo's declaration that she would give up her silver cutlery to show that she would be no different to other citizens [1], for detecting poisons, it would not make a difference whether she used silver cutlery or not. Silver has the ability to detect arsenic containing compounds, but solid silver can only detect arsenic in sulphide forms. Comparing the mechanism and time of action, arsenic poisoning likely would not be the first choice of those seeking to rise the political ranks as it takes significantly longer than something like abrin. If abrin was used, Eun Bo would not be able to detect it with her cutlery, unless that cutlery could incorporate technology that is accessible today.

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