DIFFERENCES BETWEEN METAL INGREDIENTS IN THAI GOLDWARE IN THE PRESENT MARKET AND THE ART FROM THE EARLY AYUTTHAYA PERIOD

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ABSTRACT

The research studied about the compositions of different types of Thai goldware between the early Ayutthaya art era and the current market by analyzing what gold alloy mixed up. The research method was an expose de facto design. The total samples obtained were 116, consisting of 73 samples from ancient Ayutthaya art and 43 samples from the current marketing era. An accidental sampling was conducted. Thai goldware was analyzed by using descriptive statistics, a comparative mean and discriminant analysis via a stepwise method. The findings are: Thai goldware made from gold alloys whether gold jewelry, Buddha statues or royal accessories has an average of only 63.47 percent of the gold used in all types or equivalent to 15.24K gold. Each type has an average of almost 20 percent of copper added. In the early Ayutthaya art, it is found that copper and other metals such as cadmium and tin are important parts for mixing metals for goldware different from the initial ingredients. Similarly, in the marketing of goldware in the present era, it is found that mercury is an important factor that causes the gold mixing formula for blending metals to make Thai goldware different from the initial ingredients.

Keywords: Era of Thai goldware, Types of Thai goldware, Initial ingredients of gold alloys, Significant difference in goldware.

INTRODUCTION

Gold has been a precious metal since 4500 BC due to gold has a unique color, shininess, resistance and good conductors. Gold metal is, therefore, valuable in itself for use in jewelry and used in industries, due to a static and stable substance. Gold's virtue is both natural and socio-economic. Gold thus became a symbolic representation of power and wealth. It is no wonder why there is gold plunderage both in the modern and in the past times. Gold battles have always been a hidden component of disputes. Having more gold indicates status in politics, government, economy and social standards that include culture. Pure gold has a density of 19.3 g/cm^3 when water is 1, making it quite heavy compared to other metals of the same volume. Gold has a relatively low hardness of only 2.5 Mohs-3 Mohs; hence it can easily be scratched (Jingbei, 2015; Liu, 2015; Gong, 2015; Li, 2015; Moore, 2015; Scanley, 2015; Walker, 2015; Broadbridge, 2015 & Schroers, 2015). Furthermore, gold is a soft metal and therefore it can be easily beaten into sheets or pulled into strips. This means that gold can be manipulated as you wish even though the melting point of gold is as high as 1,063°C. To make gold harder to prepare for use in items, especially jewelry, other metals must be added to the gold to suit its uses. Natural gold that has been mixed with various metals is called a gold alloy. This is mostly

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used as containers, decorations and Buddha statues which are collectively called goldware.

The international unit of measurement for Thai gold jewelry adopts the gold purity unit as karats. However, Thai people like to call it “Thong K” which is the abbreviation is the name of the unit karat (purity). Therefore, 24 K gold is comparable to 100 percent pure gold. It may contain no more than 0.01 percent of other metals. For Thai people, the unit of measurement for weight commonly used is baht. One baht of gold is equivalent to 15.244 grams. Therefore 1 baht of gold does not necessarily mean that it is 100 percent pure gold (Pi, 2022; Ploymukda, 2022; Boripon, 2022; Kwansakul, 2022; Suteerattanapirom, 2022 & Pryce, 2022).

The weight of Thai gold jewelry is not only measured in baht but also measured in specified percentages of gold ingredients, for example, one baht for a gold bar in Thailand usually contains 96.5 percent pure gold. The percentage of these ingredients is the standard for setting gold bar in Thailand. As for gold jewelry, the standard gold content is set at 92.5 percent or 90 percent, which is accepted by the Thailand gold traders association. Gold jewelry/gold alloy made outside of the Thailand gold traders association will have an uncertain amount of real gold mixed in it. The lowest has a gold content equivalent to only 9-carat gold.

The standard measurement unit (baht) used in Thailand means that the exact amount of pure gold is unknown leading to a potentially untrustworthy goldsmith mixing pure gold into gold alloys, not following the buyer's agreement. Therefore, hiring a government agency or private company to inspect authentic proportions is needed. A tool was thus developed to measure the purity of gold. There are many methods, which can be divided into simple testing methods and chemical methods, but the most popular is using a special technique called fire assay and cupellation, which will report the details of metal composition in Thai goldware.

MATERIALS AND METHODS

There has been quite a bit of research done to find the ingredients in goldware, with goldsmiths trying to improve the ingredients to suit the work piece appropriately. Pure gold or 24 K fine gold which must have genuine gold content not less than 99.7 percent. If it is more than 99.99 percent, it will become proof gold, which is the standard of pure gold that is internationally accepted. When adding various metal ingredients, it turns that pure gold into gold alloys. Goldware, especially jewelry, is usually made up of silver, copper and zinc. However, goldsmiths may mix other metals to make gold alloys with a formula suitable for the gold piece. Goldware in the current trading market often uses a mixture called gold 585.

It is a gold workpiece that contains 58.5 percent gold and the remaining 41.49 percent of other metals used in the mix. Most often consists of silver and copper. In addition to this mixture called, 375 and 750 change the color of the goldware. White gold is a popular color made by coating gold with rhodium to give it a radiant white color. Yellow gold was the original popular color for Europeans by alloying silver metal that depends on what level of golden yellow color you want it to be. Rose gold is mixed with silver and copper. Therefore, what determined the color gold depends on the metal added and in the specified proportions as shown in the figure below (Seng, 2020; Daly, 2020; Mckinnon, 2020; Parnell, 2020; Feener, 2020; Majewski, 2020; Ismail, 2020 & Sieh, 2020).

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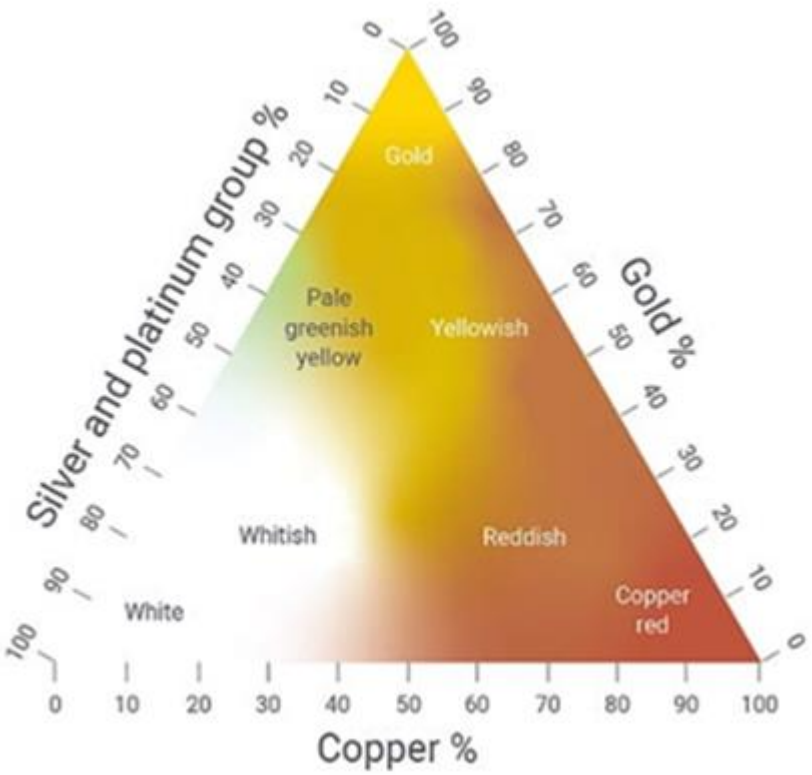

Figure 1

DIFFERENT COLOURS OF GOLD, SILVER AND COPPER ALLOYS

However, the basic formula for mixing metals in goldware for Westerners consists of copper, silver, nickel, palladium and zinc which is different from the goldware of the Thai current market and the gold art of the early Ayutthaya period. Most of them imitate the western international formulas mentioned above even in Thai government agencies. Similarly, other research works are often based on the studies of researchers abroad, making the results of Thai goldware not much different from goldware in the international market. However, Renu Tamthai has emphasized methods for analyzing the ingredients of Thai goldware. Nevertheless, the best method that gives correct, accurate results commonly used is a method called fire assay and cupellation, which is a method used in the chemistry division of the department of science service. At present, there are tools to find ingredients in goldware more easily by the New MNT-A5 gold jewelry ingredient search machine (new software with more accuracy and less error) that can analyze the composition of metal elements in goldware by screening X-rays and know the results in 5 minutes, known as X-ray fluorescent spectrometry (Merchant, 1998).

Research Objectives

The production of Thai goldware has been around for a long time, what does this mean? Accordingly, you have to explain what Suvarnabhumi means. Thai goldware has been found in archeology for thousands of years. Old Thai goldware is often discovered randomly from digs in various areas. Especially during the second fall of Ayutthaya, it is systematically stored in pagodas, stupas or tombs that Thais collectively call hide repository/crypt (“Gru”). There are quite a few crypts in Thailand that it known to hide collections of ancient objects. However, they

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may be damaged somewhat over time, especially by illegally digging the crypt by villagers, before the authorities such as the fine arts department had access to them. The crypt could have been built by anyone, but most were high-class people, especially the king and royalty. Therefore, there was quite often plenty of Thai goldware kept in the crypts. The largest Thai crypt in which a large number of King's belongings were found was the stupa built by Chao Sam Phraya in 1967 B.E. or 1424 A.D. The items found, dated back to the reign of king Nakharinthrathirat, who was the father of Chao Sam Phraya. The crypt is divided into 3 floors: The lowest floor next to the ground is where the Buddha's relics are kept and various gold ornaments to pay homage to Lord Buddha. The second or middle floor is where the Thai King's goldware is kept, used as royal accessories or royal decorations for the king. The top floor is elevated from the ground and must be accessed by stairs (Ljungberg, 2003 & Edwards, 2003). This room contained mostly small amounts of Thai goldware compared to the previous two floors. Most of the items were Shin alloys, which were popular in that era. The King's followers put their belongings in to show their loyalty and gratitude to his majesty. Most of them are Buddha amulets, both large and small in size, made from a metal alloy called "Shin". Most of the items found in the crypt can be divided into 3 categories: Goldware that represents the royal title of the king and Thai gold pieces of stuff related to his majesty, the Lord Buddha, especially Buddha images or amulets. The final category is general jewelry for all elites and laymen.

For Thai gold jewelry in the present era that is produced for marketing, different compositions may be used. The King's items of ancient Ayutthaya use a lot of mixed gold metal proportions that are surprisingly less than that of the current goldware market. Thai goldware in the modern era is in the form of industrial products. There may be a fineness of the workpiece, especially gemstones, that looks better than the traditional one because in ancient times was also decorated with stained glass. The methods of decorations are not as detailed as modern craftsmanship who have modern tools and techniques to help them create workpieces. In this research, there is no access to goldware that is royal items and royal decorations of modern monarchs. Therefore, there is no information regarding modern monarchs. From historical goldware, it would be interesting to study and research the compositions of different types of Thai goldware between the early Ayutthaya art era, over six hundred years ago, with Thai goldware in the current market; by analyzing the different compositions used in the two different eras, a description could be formed regarding the differences.

Research Questions

1. Survey and the analysis of what general gold alloy consists of what ingredients, what quantity and how many types of metal are in each formula/equation.

2. Classifying goldware based on ingredients of whether types of Thai goldware or eras of producing them.

Research Methodology

The research method used was an expose de facto design. It is to search for answers from the retrospective statistical data collection. The method used to answer the research questions, in which facts used in testing are already gathered from available data and will be re-collected while the information about the research is already embedded in the research field. There are two fields here: Collecting data from Thai goldware from the early Ayutthaya period from the crypt in Wat Ratchaburana. We have tried to collect as many items of Thai goldware as possible by using a special tool that uses irradiation on accessible parts of Thai goldware from the early

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Ayutthaya period. This was done by selecting only one random point on the material to measure the metal composition of 73 pieces of Thai goldware in ancient Ayutthaya art. We took the specimens to measure the metals that were used to make Thai goldware that entered the market; a total of 43 pieces were analyzed. Furthermore, we interviewed various goldsmiths whose work is currently on the market. Then we took each sample material and selected at random for a single point on the material to measure the metal ingredient of Thai goldware produced for sale in the market then compared it to confirm information asked from the interviews (Thomas, 2015; Harper, 2015; Nassar, 2015 & Reck, 2015). In summary, the total number of samples obtained was 116, consisting of 73 samples from ancient Ayutthaya art, accounting for 62.9 percent. The samples from the current marketing era consist of 43 pieces or 37.1 percent. This number of samples was obtained because the samples had prices and values that would be hard to reach the target. There are expenses and obstructions for checking metal compositions in Thai goldware. In particular, Thai goldware in the royal court is inaccessible in modern times. The number of samples is shown in Table 1.

Table 1
PERIODS OF GOLDWARE

Timing of arts	Frequency	Valid percent
Ancient Ayutthaya arts	73	62.9
Today arts	43	37.1
Total	116	100

The number of samples in each era can be classified into 3 types of Thai goldware (Table 2): First is, jewelry 56 pieces. Second, is the Buddha image and accessories related to 25 pieces. And lastly, Royal equipment for the king was 35 pieces. The type of Thai goldware that is the most easily accessible is jewelry. As for works related to religion, especially in the form of Buddha statues and amulets, there is not much in the making of gold. Thai goldware which is royal equipment, especially royal regalia, was a large amount of production in the early Ayutthaya period. However, there are difficulties in obtaining the work pieces of royal equipment in the present era.

Table 2
TYPES OF GOLDWARE

Types of arts	Frequency (pieces)	Valid percent
Jewelry	56	48.3
Buddha image	25	21.6
Royal equipment for the king	35	30.2
Total	116	100

To collect data from the sample, accidental sampling was used. Samples were collected if they had been seen and could be accessed by accidental sampling. Once the number of samples has been obtained, they are taken to determine the metal composition of the gold alloys, which is calculated as a percentage of the weight that makes up that workpiece of the goldware. For this purpose, samples of each type of each era have been collected for examination. Finding the percentages of metal ingredients in a piece of gold was done, using a Thai goldware irradiation detector that is currently available on the market. At the same time, data was collected to detect the percentage of weight in the gold pieces using X-ray-emitting devices to detect the ingredients in Thai goldware of the early Ayutthaya age. The information obtained was used to compare the

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changes in terms of both the number and quantity of ingredients in Thai goldware over the past six hundred years and the ingredients of goldware in the current market. How much have ingredients been changed in goldware when comparing the traditional Ayutthaya art with the goldware in the current market? (Bertram, 2006; Bertram, 2006 & Thomas, 2006).

Operational Definitions

1. The era of Thai goldware here will be divided into the era of workpieces of Thai goldware from works of art from the early Ayutthaya period founded in the crypt dating back to 1424 AD or not less than 600 years ago and Thai goldware that is currently produced for use in marketing, which may use modern technology to help in the production of workpieces.

2. There are three important types of Thai goldware: General gold jewelry refers to jewelry used in clothing, including materials and utensils made of gold alloy, Buddha image refers to a statue of Lord Buddha Maha Samana Gotama including decorations used in religion and belief ritual and royal equipment means utensils, implements and all things made to symbolize the King. Thai goldware in the present era, only two types can be studied: Jewelry and Buddha images and things related to beliefs. As for the types of Thai goldware that are royal implement items or accessories of honor due to limited access, there is no information on this.

3. Thai goldware here refers only to gold alloys, not including pure gold bars. Goldware has gold as the main or important metal, which is mixed with several various metal elements to make it colorful, easy to design and valuable for different purposes. This makes the proportion of gold alloys in various workpieces different as well. Rather, in the exploration of the work, it was found that a total of 11 metal elements are used, excluding other metals (odds and ends). That can be found in small quantities in a very small number of pieces as well.

4. Other metals refer to miscellaneous metal elements that are mixed in very small amounts in Thai goldware. It is found in only a few pieces of goldware, such as cadmium and tin.

RESULTS

Data Analysis

From the collected data, statistics will be selected that can answer the questions in this research. Answering the first question will require statistical analysis, averaging descriptive statistics in general and considering the details of the gold alloys. Gold alloys from each era, in each type of Thai goldware, were analyzed using a comparative mean. This will give an overview of the ingredients in Thai goldware according to question number 1.

The 3rd statistic used for the second question is discriminant analysis, which uses linear equations conducted *via* a stepwise method, to determine what formulates the types of Thai goldware regardless of the same era or whether they have been found in a different era or not.

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Findings

General formulas for producing Thai goldware using various alloys can be divided into metal ingredients shown in the overall figure of Thai goldware as follows:

If considering Thai goldware, no matter what type and no matter what era, the ingredients of Thai goldware were examined. We found that Thai goldware consists of a mixture of 11 metals and a small amount of other miscellaneous metals, most of which are tin and cadmium. A total of 116 pieces of Thai goldware, always has the highest amount of gold on average. Nonetheless, it was found that this does not correspond to the beliefs of most people who usually think that gold alloys will contain at least 75 percent, 80 percent or 92.5 percent gold according to the standards for purchasing gold internationally and in Thailand. Most of the goldwares contain only two-thirds elemental gold. The ratio of the amount of gold is quite different in each workpiece of Thai goldware. This is because some pieces may contain more than 80 percent gold and others contain only one-third gold. In the prehistoric era, people in society prefer to use bronze, as seen in Lopburi art. It is therefore not surprising that Thai goldware also contains a large amount of copper next to gold. This is no different from modern Western society. And there is copper mixed in almost one-fifth of the piece. The level of copper is variable, with some pieces containing large quantities and some pieces containing very little.

It is not then surprising that Thai goldware contains the third highest amount of mercury, almost one-twentieth part. This is because mercury is a liquid metal that shimmers with amazing beauty. According to belief, it hides mysteries and magical powers. The early Ayutthaya era changed from the Bronze age to the Shin age, which consisted of lead and tin. It is called the Shin era which may add a little bit of mercury. The Shin period was very short, although the workpiece came out beautiful, with a shiny gray texture like it was coated with silver. However, the case of deaths, likely from the toxicity of mercury and/or lead, caused mercury-lead mixing to be abandoned. In the present era, some people still use mercury amalgams, which are more beautiful than lead alone. Nevertheless, it was not as beautiful as the early Ayutthaya period. Surprisingly, the majority of ingredients used tend to be white or shiny metals in at least the next six elements of Thai goldware. The top three are zinc, silver and iron, with more than 3 percent for each. These elements have a silvery color when there is no rust on them, so the gold mixture will be more of a soft yellow color than an orange-golden color. Additionally, there are mixtures of shiny whitish-gray metals consisting of rhenium, nickel and palladium, all of which have a silver-like luster. Especially the addition of nickel and palladium, which have similar properties where they are: Silvery white, a very hard metal that has a high melting point, resistant to corrosion and difficult to find in the mix. They make the workpiece more durable. It is noteworthy that arsenic was added in a very small amount, only 0.1 percent or 1 in 1000 parts. Arsenic is a metalloid. Yet, the use does not seem to match with Thai goldware or international goldware. It is understood that storing Thai goldware including silver and gold tinsel cloth, which may be chewed by animals. Arsenic may help protect Thai goldware from damage by insect biting. There is also another ingredient in the mixture, but in very small amounts which is manganese with only one part per million. This may be because manganese decreases the heat energy required to melt. Other miscellaneous ingredients are added in very small amounts and only in a few workpieces like Tin and Cadmium (Thomas, 2015; Harper, 2015; Nassar, 2015; Nuss, 2015 & Reck, 2015). In summary, an overview of Thai goldware above contains ingredients that are different from international standards. It is a specific characteristic of

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mixing metals into Thai goldware. It uses a variety of metals with properties that make Thai gold jewelry last a long time without degrading, apart from the deliberate destruction by humans themselves.

Table 3
THE COMBINATION OF METALS USED TO CREATE THAI GOLD ART AS A WHOLE

Overall	Gold alloys	Mean	SD
1.	% Gold	63.4689	14.80367
2.	% Copper	18.9088	15.1021
3.	% Mercury	4.1104	4.76256
4.	% Zinc	3.7182	5.5425
5.	% Silver	3.4141	7.61053
6.	% Iron	3.112	3.77663
7.	% Rhenium	1.576	5.06894
8.	% Nickel	1.2495	4.29796
9.	% Palladium	0.2174	2.32105
10.	% Arsenic	0.0952	0.57851
11.	% Manganese	0.0009	0.00928
12.	% Others	0.1303	0.39731

General formula for determining the metal composition of Thai goldware, classified by type according to its era. This can be seen from Table 5, if you do not pay attention to the era. Each type of Thai goldware certainly included gold, copper, mercury, zinc, silver, iron, rhenium, nickel, palladium, arsenic, manganese and others. If not including others, Thai gold alloys that are used to make goldware have a total of 11 metal elements. When analyzing the variance among these metals, there are almost 11 basis/initial metals.

Some metals are used in varying amounts in the three types of goldware. This causes the components in each type of Thai goldware to have different formulas due to the following metal factors; which are silver, nickel, iron, mercury and rhenium. The percentage of silver, nickel, iron, mercury and rhenium used, can indicate its involvement in making goldware different. Therefore, the gold alloys used are not the same. The remaining metals used, provide little difference from another type of initial Thai gold alloy (Jirang, 2008 & Zhang, 2008).

The differences in proportions used in Thai goldware when classified by the form or type of work piece used in each era are work pieces of ancient Ayutthaya art and work pieces of today's era. It can be seen that Thai goldware classified by types under the early Ayutthaya period will have a mixture of metals that is quite different from the ingredients of the present era. The reasons why are as follows:

Gold alloy in the form of jewelry uses a wider variety of metals than in the present era. Gold found in jewelry in the early Ayutthaya period is in higher quantities than in the current market. Gold mixed in the early Ayutthaya period had an average of almost 74 percent, similar to 18 K gold. While the average amount of gold mixed in the jewelry of the current market is only 57.55 percent or equivalent to 13.81 percent or about 14 K gold. It shows that Thai goldware in the present era has less gold mixed to the point where there is a noticeable difference. Consumers do not realize that the average quality of goldware today has greatly decreased.

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Today's goldsmiths are mixing metals, especially copper, to push the color to make the ingredients look more valuable. There was also a greater reduction in the proportion and quantity of silver-colored minerals compared to goldware in the early Ayutthaya period. This can be seen from the ranking of the average ratios of the metals mixed into them. The jewelry workpieces from the early Ayutthaya period contain elements as follows: Gold, nickel, silver and copper in ratios higher than 60 percent for each. The average amount of mercury, iron, rhenium and zinc decrease respectively under 10 percent. The remaining materials, namely arsenic, palladium and other metals make up less than one percent. However, there are no manganese minerals. As for gold alloy, used in jewelry in the current market, the gold content is an average of only 57.55 percent or only 14 K gold jewelry.

There are other metals as well mixed in both smaller amounts and numbers. The highest mineral content next to gold is copper at 25.59 percent, with silver, nickel and zinc respectively, averaging only the highest single digits. It is also found that palladium, manganese and other metal elements average less than one percent. In addition, there was no mixing of mercury and arsenic at all, which is dangerous and rhenium is rarely found. Humans in today's society understand these deadly terrible elements very well.

In the case of the type of gold alloy used to make Buddha images, amulets and gold equipment related to religion, the proportion of metal alloy will be different from jewelry; whether it is the early Ayutthaya art or gold alloy related to religion in the market today. Gold art created in connection with Buddhism in the early Ayutthaya period had a much lower gold content, only 62.18 percent on average, compared to gold jewelry from the same era which had 14 percent more gold elements than the average. The second order of higher magnitude is copper. However, the average value is 16.31 percent, which uses a small amount of copper compared to gold.

The formula for making Buddha statues and religious matters uses ingredients respectively such as mercury, zinc, iron, rhenium and silver. It is worth noting that in the past they were produced to have a shiny silvery color. Mercury was an element used in the formula for making Buddha amulets and items related to religion until today because it is considered a sacred substance. Goldsmiths do not like to use silver, even though it is a valuable object, because silver according to peoples' understanding should have a higher proportion for this formula.

Surprisingly, the legacy of the iron age remains as well as the bronze age because iron was still mixed into goldware but it is not very popular these days. However, arsenic was added and the amount of palladium decreased a little bit because arsenic is a toxic substance and palladium is a rare metal. Moreover, manganese metal is not even popular in the production of Buddha statues and related parts.

As for the types of Buddha images and those related to religion in the current market. There is instead, the highest amount of gold was at, 77.86 percent, equivalent to 18.69 K gold and 20 percent more than gold mixed into modern jewelry. This is because it is popular to cast gold amulets for sale in the amulet market. Moreover, Buddhism has firmly established its roots compared to six hundred years ago. Strong faith in Buddhism has led to the increased use of gold metal and gold alloys are becoming scarcer.

The metal elements used to calculate the average percentage in one digit in order are as follows: Mercury, copper, iron, silver, zinc and other metals. The remaining metal elements were much less used, the average is less than one percent. Some metals were not added, especially rare metals such

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as nickel, palladium, rhenium and manganese, which made the Buddha image have a more brilliant gold appearance which creates more value in terms of price and mentality.

In the case of royal accessories, goldware was used in both the royal court and gold jewelry displaying royal titles in the early Ayutthaya period. Surprisingly, the average amount of gold used was only 60.42 percent. This caused so misunderstanding that royal consumer items should have much more gold mixed in alloys, on the other hand, they were less.

However, an average of one-third of the copper is used in gold to push the color to an orange-golden color. Then four other metals are mixed in to make it look shinier, with an average percentage of one digit as follows: Zinc, mercury, iron and rhenium.

For the remaining metal elements, the average values are in decimals which include: Arsenic, silver, nickel and others. No mixture with the elements palladium and manganese were found. Those ingredients, thus, cannot be obtained percentages about the art of goldware for the king. As for the current consumer items provided by his Majesty's agencies, it is impossible to access information in this case (Rod, 2006; Chaudhry, 2006; Boxall, 2006 & Hull, 2006).

In summary, Thai goldware made from gold alloys whether gold jewelry, Buddha statues and items related to religion and royal accessories have an average of only 63.47 percent of the gold used in all types of gold items or equivalent to 15.24 K gold. Each type has an average of less than 70 percent of gold, with an average of almost 20 percent of copper added. As a result, it can push the orange-golden color.

Furthermore, there are various metal combinations. The rest elements are scattered in an average amount of a percentage as small as one digit. It is worth noting that manganese is not commonly added to any type of goldware except in jewelry that is produced for use in the current market.

Table 4
THE GOLD ALLOYS IN THAI GOLDWARE ARE CLASSIFIED BY TYPE, WHICH IS DETERMINED BY THE ERA IN WHICH THEY WERE MADE

Gold alloys	Ayutthaya ancient arts							
	Jewelry (21 pieces)		Buddha image (17)		Royal equipment (35)		Total (73)	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
% Gold	73.97	8.84223	62.1794	14.74366	60.4223	15.7616	14.92633	0.03162
% Nickel	64.7288	14.92633	0.0518	0.0864	0.0214	0.06878	0.0252	6642
% Silver	62.1794	14.74366	1.8212	5.28017	0.0866	0.14389	0.6303	2.83984
% Copper	60.4223	15.7616	16.3094	13.8163	22.362	14.12981	17.1292	13.40172
% Mercury	6.0305	4.28717	6.4094	5.18322	5.0169	4.96159	5.6327	4.80349
% Iron	4.7438	4.20391	5.1847	4.40311	4.2426	3.4415	4.6062	3.8677
% Rhenium	3.2905	7.13028	2.3294	5.76493	2.1177	5.98482	2.5044	6.21949
% Zinc	2.0129	3.30957	5.3788	6.77623	5.4743	7.08773	4.4563	6.27814
% Arsenic	0.2567	1.17619	0.0106	0.04366	0.1563	0.53132	0.1512	0.72522
% Others	0.0338	0.0782	0.3224	0.53958	0.1	0.24137	0.1327	0.32523
% Palladium	0.0081	0.02786	0.0029	0.01213	0	0	0.003	0.01613
% Manganese	0	0	0	0	0	0	0	0

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Gold alloys	Today arts							
	Jewelry (35 pieces)		Buddha image (8)		Royal equipment (inaccessible)		Total (56)	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
% Gold	57.5457	12.90332	77.8863	8.3946	-	-	61.33	14.51456
% Copper	25.59	16.93452	5.9175	7.58419	-	-	21.93	17.37071
% Silver	9.3329	10.77065	2.9225	6.99132	-	-	8.1402	10.41286
% Nickel	4.0886	7.11253	0	0	-	-	6.3279	6.59879
% Zinc	2.6057	3.97368	1.85	2.59029	-	-	2.4561	3.74022
% Palladium	0.7143	4.22577	0	0	-	-	0.5814	3.81246
% Others	0.1257	0.54791	0.1288	0.21709	-	-	0.1263	0.50088
% Manganese	0.0029	0.0169	0	0	-	-	0.0023	0.01525
% Iron	0	0	3.0925	2.95772	-	-	0.5753	1.71486
% Mercury	0	0	8.2025	2.74253	-	-	1.526	3.4183
% Rhenium	0	0	0	0	-	-	0	0
% Arsenic	0	0	0	0	-	-	0	0
Gold alloys	**Grand totals**							
	Jewelry (56)		**Buddha image (25)**		**Royal equipment (35)**		**Total (116 pieces)**	
	Mean	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**
% Gold	63.7048	13.99033	67.2056	14.87919	60.4223	15.7616	63.4689	14.80367
% Copper	19.3955	16.0044	12.984	12.98133	22.362	14.12981	18.9088	15.1021
% Silver	6.0477	9.583	2.1736	5.75482	0.0866	0.14389	3.4141	7.61053
% Nickel	2.5591	5.93655	0.0352	0.07473	0.0214	.0687X8	1.2495	4.29796
% Zinc	2.3834	3.71861	4.2496	5.94904	5.4743	7.08773	3.7182	5.5425
% Mercury	2.2614	3.91944	6.9832	4.56432	5.0169	4.96159	4.1104	4.76256
% Iron	1.7789	3.43463	4.5152	4.05815	4.2426	3.4415	3.112	3.77663
% Rhenium	1.2339	4.59035	1.584	4.83593	2.1177	5.98482	1.576	5.06894
% Palladium	0.4495	3.3404	0.002	0.01	0	0	0.2174	2.32105
% Arsenic	0.0963	0.72027	0.0072	0.036	0.1563	0.53132	0.0952	0.57851
% Others	0.0913	0.43568	0.2604	0.46512	0.1	0.24137	0.1303	0.39731
% Manganese	0.0018	0.01336	0	0	0	0	0.0009	0.00928

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Table 5 ANOVA TABLE				
Gold alloys of Thai goldware	**F**	**Sig**	**Eta**	**Eta squared**
% Silver * timing of arts	33.885	0	0.479	0.229
% Nickel * timing of arts	18.396	0	0.373	0.139
% Iron * timing of arts	41.748	0	0.518	0.268
% Mercury * timing of arts	24.175	0	0.418	0.175
% Rhenium * timing of arts	6.947	0.01	0.24	0.057
% Zinc * timing of arts	3.571	0.061	0.174	0.03
% Total * timing of arts	3.5	0.064	0.173	0.03
% Copper * timing of arts	2.777	0.098	0.154	0.024
% Arsenic * timing of arts	1.863	0.175	0.137	0.016
% Manganese * timing of arts	1.708	0.194	0.122	0.015
% Palladium * timing of arts	1.69	0.196	0.121	0.015
% Gold * timing of arts	1.432	0.234	0.111	0.012
% Others * timing of arts	0.007	0.923	0.008	0

The formula for producing Thai goldware is classified according to the types produced in different eras. Concerning the first question, we learned that Thai goldware, regardless of era and type, is mixed with 11 metals. This does not include other miscellaneous metals that are in small quantities and found in a small number of pieces. However, even with such combinations of initial metal elements, it was found that some metal elements are still added to create differences between each type of goldware. Rather, it can be formulated into a formula or equation for gold alloys in each era as follows.

Studying the formulas for each type of goldware in the early Ayutthaya period, it was found that copper metal was the most important factor. Other metals that made the recipe for each type of Thai goldware were different in value. Mixing copper and other metals to differentiate each type of gold alloy in the early Ayutthaya period can be summarized as the following formula or equation:

1. Jewelry=0.063% copper-0.385% others-1.377
2. Buddha image=0.091% copper-2.276% others-2.205
3. Royal equipment=0.153% copper-0.759% others-2.775

The above formula or equation reveals that each type of goldware is different. It is produced or prepared to suit the use of Thai goldware after mixing with other metals. It was found to be amazing that the royal consumer items had instead the highest percentage of average copper as shown in equation 3. There were even lower quantities of miscellaneous metals used. They are already mixed in proportion which makes the mixture of other metal elements not very different. However, these miscellaneous metals may reduce the quality of goldware such as color, design or brilliance. Thai goldware in the form of Buddha statues and related parts has a modest average percentage of copper compared to other types of Thai goldware (John, 2002). It is alloyed with more miscellaneous metals. While gold jewelry adds the least amount of copper and other miscellaneous metals. The types of Thai goldware still have different constant values. Thai goldware is well-known since the

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number and quantity of the initial metal combinations in each type of Thai goldware in the early Ayutthaya period were quite different. All alloys at the starting point are not equal either.

Table 6
DISCRIMINANT ANALYSIS: ANCIENT AYUTTHAYA PERIOD VARIABLES ENTERED/REMOVED

Step	Entered	Wilks' lambda							
		Statistic	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	%Copper	0.82	1	2	70	7.705	2	70	0.001
2	%Others	0.72	2	2	70	6.168	4	138	0

Classification function coefficients

Metal ingredients	Goldware		
	Jewelry	Buddha image	Royal equipment
%Copper	0.063	0.091	0.153
%Others	-0.385	2.276	-0.759
(Constant)	-1.377	-2.205	-2.775

Note: Fisher's linear discriminant functions.

At each step, the variable that minimizes the overall Wilks' Lambda is entered.

1. Maximum number of steps is 22.
2. Minimum partial F to enter is 3.84.
3. Maximum partial F to remove is 2.71.
4. F level, tolerance or VIN is insufficient for further computation.

Studying the formulas/equations for each type of goldware in the present era where Thai goldware is traded in the gold jewelry market, it was found that mercury metal is an important factor that causes the formulas for each type of Thai goldware to be different. It can be summarized as a formula or equation as follows.

1. Jewelry=0.0001% mercury-0.693

2. Buddha image=0.6387% mercury-26.89

Equation 3 will not be included in this section because the data source is not accessible.

The above equation reveals that each type of goldware is different in response to the suitability of using Thai goldware after having other metals as a starting point. It is not surprising that Thai goldware, in the form of Buddha images and related objects, contains a lot of mercury when compared with other types of Thai goldware. This is because mercury is a substance that appears different from other metal elements. Thai people believe that mercury has mystical power and for this reason, mercury is used as an element in goldware related to Buddhism and beliefs. Gold jewelry, on the other hand, may contain a smaller amount of mercury which was added to create a slight difference from other types of gold jewelry. The type of Thai goldware remains a constant in the equation. This shows the differences between the quantity and the kind of alloying metals in

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each type of Thai goldware in the current market which are not the same. In particular, Thai goldware, which is in the form of Buddhism, has other metal elements that are not mentioned in the equation being used for making gold alloys in relatively smaller amounts than jewelry.

The answers to question number 2. We found that many metals were added as the basis for the production of Thai goldware, with unequal proportions of metal from the answer to question number 1. However, it was found that certain metal elements are important indicators that make the equations for producing each type of Thai goldware different from others. Going back to the early Ayutthaya art, it was found that copper metal and other miscellaneous metals such as cadmium and tin are important parts that make the formula for making alloys to make goldware different from the original ingredients. Similarly, in making goldware in the modern era, it is found that mercury is an important factor that makes the equation for mixing gold with other metals different from the initialed ingredient by simply adding mercury to the Buddha statue's case and other corresponding parts.

Table 7
DISCRIMINANT ANALYSIS: TODAY'S PERIOD VARIABLES ENTERED/REMOVED

Step	Entered	Wilks' Lambda							
		Statistic	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	% Mercury	0.107	1	1	41	341.165	1	41	0

Classification function coefficients		
Metal ingredients	Goldware	
	Jewelry	Buddha image
% Mercury	0.001	6.387
(Constant)	-0.693	-26.89

Note: Fisher's linear discriminant functions

At each step, the variable that minimizes the overall Wilks' Lambda is entered.

1. Maximum number of steps is 22.
2. Minimum partial F to enter is 3.84.
3. Maximum partial F to remove is 2.71.
4. F level, tolerance or VIN is insufficient for further computation.

DISCUSSION

The discovery of the answer was found in people of the same descent located in the original area. Thai goldware is made with only 11 important metals, which may seem complicated compared to the current goldware recipes. They contain a smaller number of metals in present Thai goldware. Although current Thai goldware has the same main ingredients as goldware internationally. Thai goldware from the early Ayutthaya period will have more complicated components than current Thai goldware and possibly more than goldware from other nations. This is because the antique Thai goldware was created as a work of art, not for marketing. Therefore, gold alloys are used to make ancient Thai goldware that may look more complicated. It is almost unbelievable that toxic substances are mixed into the gold alloys to keep out insects. This makes ancient Thai goldware not suffer from insects or rats attacking it, even if it has been secretly drilled into the crypt. Rare minerals may also be found in the ingredients of traditional works of gold art. This rarely happens with gold jewelry in the modern day. This is because the

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crafts man may not have been aware of the ingredients of Thai goldware from ancient times that were kept as a secret formula. Meanwhile, modern goldware uses a limited number of metal combinations to keep costs low and to keep physical properties and design competitive in the market. Even though the land of Thailand is known as the land of gold, the use of gold as an ingredient is not as common as one might assume. However, Siam was seen as the land of gold claimed by merchants during the Renaissance period. Recognizing the ingredients in formulas for making Thai goldware makes you realize that the current goldsmith's concept is different from what is called “art” by imitating foreigners in acquiring Thai goldware at present. If you are aware of the work of ancient goldsmiths, you will know why their work has a brilliant golden color even after so much time. Part of these discoveries revealed ingredients of Thai goldware from ancient times that had never been revealed. Meanwhile, goldware nowadays looks too industrial (Hiskey, 1988 & Atluri, 1988).

CONCLUSION

From the above two questions:

1. General formula or equation for producing Thai goldware with various metal elements.
2. Classifying goldware based on ingredients of whether types of Thai goldware or eras of producing them.

When analyzing with a statistical model we found the answer as follows.

Thai goldware in the form of gold jewelry, Buddha statues and parts related to religion and royal consumer items, have an average of only 63.47 percent of the gold used in all types of goldware or equivalent to 15.24 K gold. Each type has an average gold of less than 70 percent mixed in. The average percent of copper added was almost 20 percent to push the orange-golden color even more. There are also various metal combinations, in an average percentage of only a few digits. It is worth noting that manganese is not commonly added to any type of goldware except in gold jewelry that is produced for use in the current market.

Although many metal elements may be added as the basis for the production of Thai goldware with unequal proportions of metals from the answer to question 1. It was found that there were some important metals, which were the indicators that make the formula for producing each type of Thai goldware different from other gold alloys. If we go back to the early Ayutthaya art, it is found that copper and other metals such as cadmium and tin are important parts that make the formula for mixing metals for goldware different from the initial ingredients. Similarly, in the marketing of goldware in the present era, it is found that mercury is an important factor that causes the gold mixing formula for blending metals to make Thai goldware different from the initial ingredients.

RECOMMENDATIONS

1. This research reveals the ingredients of goldware both in the past and in the present that the goldsmiths kept secret. This makes it impossible to continue to produce Thai goldware as 600 years ago. This also makes it impossible to develop the ingredients of the formula for making goldware in the past and apply it to current work to make the color of gold bright and bright for a long time.

2. Knowing the percentage of metal elements used in making Thai goldware, allows us to estimate the amount and number of metal types used appropriately for each type of goldwork.

3. The average amount of gold used by goldsmiths in work pieces from the early Ayutthaya period was not

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greater than the amount of gold used in the current market. Nevertheless, the secret of the traditional ingredients is that there are more metal elements. Including the use of rare minerals and toxic substances, it is worth further researching the reasons for selecting such substances.

4. When the crypt was illegally opened around 1957, it was found that many of the people who illegally dug the crypt went crazy, lost their minds and died. Some people buy many amulets found in the crypt that the government has opened for distribution to the general public to bring income to build a museum in Ayutthaya. It was found that many people had died due to the contamination of toxic substances in the goldware. This matter is something worth studying further. Even if there is a misfortune that destroys life to the point of being viewed as a superstition. However, fortunately, the goldware did not change much in color. That is a reason how to make goldware so that it is safe for the maker and user as well as the color does not fade or change. Perhaps it was necessary to find other metals from our old knowledge to replace them.

5. Mixing metal elements of Thai goldware in the current marketing era is produced for competition and cost reduction. Therefore, a mixture of a small number of metallic elements is used. It does not only use a small amount of gold but there are also gems and modern technology that will make Thai goldware still sustainable and popular. However, the ingredients of Thai goldware from the early Ayutthaya period used more kinds of metal. Sapphire in the present time is colorful meanwhile stained to mix in the early Ayutthaya period. Some metal elements that is likely to be unusable but it became a matter of concealment. We may not have an idea of why we chose to use such formulas or equations and how much will it help further the development of Thai goldware in the present era.

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Received: 12-Mar-2024, Manuscript No. IJE-24-15098; **Editor assigned:** 15-Mar-2024, Pre QC No. IJE-24-15098 (PQ); **Reviewed:** 29-Mar-2024, QC No. IJE-24-15098; **Revised:** 15-July-2024, Manuscript No. IJE-24-15098 (R); **Published:** 12-Aug-2024

Citation Information: Sotanasathien, S., Sotanasathien, S., (2024). Differences between Metal Ingredients in Thai Goldware in the Present Market and the Art from the Early Ayutthaya Period. *International Journal of Entrepreneurship, 28*(5), 1-17.