SECRET GOLD ALLOY'S FORMULAS FOR THAI GOLDWARE BETWEEN THE PRESENT MARKET AND THE ART FROM THE EARLY AYUTTHAYA PERIOD

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ABSTRACT

The research studied the compositions of different types of Thai goldware between the early Ayutthaya art period and the current market era 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 gold alloy formulas were analyzed by using multiple regression analysis via a stepwise method. The findings are: It can be said that traditional gold alloys are better a little bit quality than gold alloys in the marketing world. We also found that there have never been disclosed two secret formulas for making gold alloys in those days, meanwhile making gold alloys is 11 formulas in these days. In the early Ayutthaya periods, one is a simple formula but the other formula is very sophisticated due to plenty of metals correlating by corresponding or converting each other with gold. However, there are eleven formulas in the present market era. Likewise, they are three simple formulas comprising a few metals. The other formulas are more complicated since a large number of metals correspondingly and inversely with gold. Fortunately, we find out all the formulas from the research. Nevertheless, at least 5 metals always make gold alloys different during the eras and all five metals usually correlate with gold. The rest metals may also blend in gold alloys to garnish a special Thai goldware.

Keywords: Formulas of Thai gold alloys, The early Ayutthaya period, The current market era, Correlating alloys with gold.

INTRODUCTION

Gold has been a precious metal since 4,500 BC due to gold is unique color, shininess, resistance and good conductivity. Gold metal is, therefore, valuable in itself for use in jewelry and use in industries, due to it being 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 the status in politics, government, economies and social standards including 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 gold alloys. This is mostly used as containers, decorations and

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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 trader's 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 workpiece 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 accepted internationally. When adding various metal ingredients, it turns 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 workpieces.

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 other remaining 41.49 percent is other ingredients most often consisting 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 determines the color gold depends on the metal kinds are added in the specified proportions. (Seng, 2020; Daly, 2020; Mckinnon, 2020; Parnell, 2020; Feener, 2020; Majewski, 2020; Ismail, 2020 & Sieh, 2020).

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 era 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 researches 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 gold alloys. Nevertheless, the best method that gives correct, accurate results commonly used is a

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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 gold alloys 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? You have to explain accordingly 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 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 date 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 are to pay homage to Lord Buddha. The second or middle floor is where the Thai King's goldware is kept and 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 gold alloys between the early Ayutthaya art era, over six hundred years ago, with Thai goldware in the current market. By analyzing the different compositions/formulas used in the two different eras, a description was formed regarding the differences.

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 recollected 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

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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 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 one-single point on the material to measure the metal ingredient of Thai gold alloys produced for sale on the market and 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 gold alloys. Particularly, 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

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 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/gold alloys in the current market. How much have ingredients thus 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

- 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 found 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. Each era contains different proportions of gold alloy compositions.

- There are three important types of Thai goldware made from gold alloys: 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 (Rod, 2006; Chaudhry, 2006; Boxall, 2006 & Hull, 2006): Jewelry and Buddha images and things related to

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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. However, the second phase of the research on gold alloys during the period or era is not involved in the three types of Thai goldware.

- Thai goldware here refers only to gold alloys, not including pure gold bars. Goldware has gold as the main part of alloys, 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, including other miscellaneous metals (odds and ends). That can be found in small quantities in a very small number of pieces as well.

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

RESULTS

Data Analysis

From the collected data, analyses will be selected that can answer the questions in this research. Answering the basic information will require statistical analysis, averaging descriptive statistics in general and considering the details of the gold alloys of each era. This will give an overview of the ingredients/alloys in Thai goldware. The statistic used for the first and the second questions is multiple regression analysis, which uses linear equations conducted *via* a stepwise method, to determine what formulates of gold alloys for Thai goldware, especially the different eras.

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 gold alloys for Thai goldware, no matter what type and no matter what era, their ingredients 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 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 gold alloys 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 less than one-third gold.

Then, it is not 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 into the Shin Age, which consisted of lead and tin. It is called the Shin era which adds 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 to be 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 gold alloys. 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

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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 tiny amounts and only in a few workpieces like Tin and Cadmium (Thomas, 2015; Harper, 2015; Nassar, 2015; Nuss, 2015 & Reck, 2015). Moreover, an overview of gold alloys for the above Thai goldware contains ingredients that are different from international standards. It is a specific characteristic of mixing metals into Thai goldware. It uses a variety of metals with properties that make Thai gold alloys last a long time without degrading, apart from the deliberate destruction by humans themselves (Table 2).

TABLE 2
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

To reply the question 1, the differences in proportions used in Thai gold alloys when classified by the periods of workpiece used in ancient Ayutthaya art and workpieces of today's era. It can be seen that Thai gold alloys under the early Ayutthaya period have a mixture of metals that are quite different from the ingredients of the present era. However, the remaining metals used, provide little difference from other types of initial Thai gold alloys (Jirang, 2008 & Zhang, 2008). Gold alloys composed of genuine gold in the main part were 64.73% or 15.54 K despite quite variations. It means that some workpieces had a wide range of around a minimal 50% gold to a maximum 80% gold due to the different types of goldware. The second metal was copper nearly 20%. It implied the legacy of the bronze age. The copper content helps to enhance the yellow-golden color of goldware to reduce the use of bulk gold to make the ingredients look more valuable. The quantity of copper was the same variations as gold. The traditional goldware in the period of ancient Ayutthaya still demanded shiny gold alloys. Therefore, they were blended with five glossy metals: Mercury, iron, zinc, rhenium and a little bit of silver. There were a few other ingredients such as arsenic, nickel, palladium and others (tin and cadmium) in Table 3. The

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rearmost metals were few and less than 1%. It may have come from natural impurity.

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 64.73% percent of the gold used in all types of gold items or equivalent to 15.54 K gold. Each type has an average of less than70 percent of gold, with an average of almost 20 percent of copper added. As a result, it can push 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.

TABLE 3
THE GOLD ALLOYS FOR THAI GOLDWARE IN AYUTHAYA'S ANCIENT ARTS

	Ayutthaya's ancient arts	
	Total (73)	
Gold alloys	**Mean**	**Sd**
% Gold	64.7288	14.92633
% Copper	17.1292	13.40172
% Mercury	5.6327	4.80349
% Iron	4.6062	3.8677
% Zinc	4.4563	6.27814
% Rhenium	2.5044	6.21949
% Silver	0.6303	2.83984
% Arsenic	0.1512	0.72522
% Others	0.1327	0.32523
% Nickel	0.0252	0.06642
% Palladium	0.003	0.01613
% Manganese	0	0

All metals in Table 3 were mixed to make gold alloys for creating goldware. The alloying of metals in unequal proportions from the base metals in Table 3 would result in several formulas of gold alloys used in early Ayutthaya art for goldware. We have found that two gold alloy formulas were popularly used in goldware in the early Ayutthaya period as shown from the data of the collected samples. The formulas were run by multiple regressions of those data. Each regression equation was replaced by each formula. The dependent variable was gold, which meant that gold was the main ingredient in making gold alloys used for Thai traditional goldware. The initial or fundamental metals composed of 11 elements together with others could generate two formulas of gold alloys shown in Table 4. According to the first question, each formula was shown in Table 5. In the early Ayutthaya period, it was found that there were two formulas for making gold alloys for use in Thai goldware. Those gold alloy formulas in Ayutthaya arts of goldware were as follows:

Gold alloys 1.1=1.725+0.027% copper

Gold alloys 1.2=1.302+0.041% copper+0.02% silver-2.477% nickel-0.004% zinc+0.015 iron+0.032% mercury-7.373% palladium+0.014% rhenium-0.127% arsenic+0.039% others

Both formulas were significantly adopted to differentiate how to mix themselves into distinguishing types of gold alloys. The first formula of the first question was gold alloys composed of copper which was one of 11 elements with others in the initial metals. This means that gold alloys of

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formula 1.1 were a mixture only between gold and copper. We usually find some ornaments made of them for gold alloys in the early period of Ayutthaya. Nevertheless, there was another formula for gold alloy 1.2, this second one was a significantly different multiple regression equation from formula 1.1 due to a more complex mixture of metals than the first gold alloy formula. Formula 1.2 included 9 metals together with miscellaneous others. Copper was only one kind of metal significant in the formula but less variations in the regression equation. Nonetheless, the rest of the metals that are influent in copper are distinguished from the first formula. The remaining metals of alloys had small amounts and some of them had inversely proportional amounts such as nickel and palladium. However, they did not affect the gold alloy quality so much, when changing the amount of each metal did not cause the gold alloy's quality to change significantly from the original metals.

TABLE 4
ANOVA[a,b]

	Model	Sum of squares	df	Mean square	F	Sig.
1	Regression	9.601	1	9.601	15.594	0
	Residual	43.714	71	0.616		
	Total	53.315	72			
2	Regression	13.63	10	1.363	2.129	0.035
	Residual	39.685	62	0.64		
	Total	53.315	72			

Note: a: a. Dependent Variable: gold alloys; b: b. Selecting only cases for Ayutthaya arts

TABLE 5
COEFFICIENTS[a,b]

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.	Correlation		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	1.725	0.15		11.525	0			
	% copper	0.027	0.007	0.424	3.949	0	0.424	0.424	0.424
2	(Constant)	1.302	0.377		3.451	0.001			
	% copper	0.041	0.012	0.644	3.436	0.001	0.424	0.4	0.376
	% silver	0.02	0.037	0.065	0.528	0.599	-0.101	0.067	0.058
	% nickel	-2.477	2.166	-0.191	-1.143	0.257	0.045	-0.144	-0.125
	% zinc	-0.004	0.027	-0.031	-0.161	0.872	0.224	-0.02	-0.018
	% iron	0.015	0.027	0.07	0.572	0.57	-0.065	0.072	0.063
	% mercury	0.032	0.029	0.179	1.094	0.278	-0.1	0.138	0.12
	% palladium	-7.373	6.252	-0.138	-1.179	0.243	-0.212	-0.148	-0.129
	% rhenium	0.014	0.021	0.099	0.661	0.511	-0.078	0.084	0.072
	% arsenic	-0.127	0.138	-0.107	-0.919	0.362	-0.045	-0.116	-0.101
	% others	0.039	0.385	0.015	0.102	0.919	0.046	0.013	0.011

Note: a: Dependent variable: Gold alloys; b: Selecting only cases for which timing of arts=ancient Ayutthaya arts

The findings of question 2 were involved in gold alloys for making Thai goldware using the less common kinds of metals. All fundamental metals of 11 kinds, except gold, were conducted to deploy 8

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kinds for gold alloys of the present market era. Copper was still used in major gold alloys almost 22% since copper has been used as the main ingredient in gold alloys from the early days to make the raw gold easier to shape. Furthermore, the copper's color looks golden color and assisted to make them more beautiful as well. Silver, nickel, zinc and mercury were taken in a single-digit percentage of gold alloys to make it brighter. The rest of the metals had amounts in decimal (Table 6) such as palladium, iron, very few manganese and other miscellaneous metals. On the other hand, in the present era, there is no use both of rhenium and arsenic, meantime in the early Ayutthaya age use of manganese. Gold alloys made of goldware in today's world were more radiant and more brilliant too.

TABLE 6
THE GOLD ALLOYS FOR THAI GOLDWARE IN THE PRESENT MARKET AGE

	Today' arts	
	Total (56)	
Gold alloys	**Mean**	**Sd**
% Gold	61.33	14.51456
% Copper	21.93	17.37071
% Silver	8.1402	10.41286
% Nickel	6.3279	6.59879
% Zinc	2.4561	3.74022
% Mercury	1.526	3.4183
% Palladium	0.5814	3.81246
% Iron	0.5753	1.71486
% Others	0.1263	0.50088
% Manganese	0.0023	0.01525
% Rhenium	0	0
% Arsenic	0	0

Gold alloys these days constructed with high technologies and modern techniques can create 11 formulas from only 8 kinds of metals and others. Those various formulas of gold alloys were opened for a person to choose more types of Thai goldware from various formulas to differentiate themselves.

Linear regressions of goldware formulas for today's arts are shown by ANOVA in Table 7. There are 11 models/formulas found in statistics. Each formula was significantly separated from each other at sig.=0.000. As a result, each formula is composed of different amounts and numbers made by metal varieties. However, these formulas generate different qualities of gold alloys for goldwares (Table 8). All formulas to correspond to question 2 for the present market era are shown as follows:

Gold alloys 2.1=1.954-0.040% silver

Gold alloys 2.2=2.045-0.043% silver-0.063% nickel

Gold alloys 2.3=1.889-0.037% silver-0.074% nickel+0.040% zinc

Gold alloys 2.4=1.525-0.023% silver-0.058% nickel+0.053+%zinc+0.002% cooper+0.024% iron+0.034% mercury-0.021% palladium+0.181% manganese+0.020% rhenium-0.080% arsenic-0.146% others

Gold alloys 2.5=1.525-0.023% silver-0.058% nickel+0.053% zinc+0.002% cooper +0.024%

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iron+0.034% mercury-0.021% palladium+0.020% rhenium-0.080% arsenic-0.147% others

Gold alloys 2.6=1.582-0.024% silver-0.061% nickel+0.054% zinc+0.022% iron+0.031% mercury -0.024% palladium+0.019% rhenium-0.081% arsenic-0.142% others

Gold alloys 2.7=1.582-0.024% silver-0.060% nickel+0.053% zinc+0.023% iron+0.029% mercury-0.024% palladium+0.019% rhenium-0.146% others

Gold alloys 2.8=1.553-0.023% silver-0.059% nickel+0.054% zinc+0.024% iron+0.031% mercury+0.020 % rhenium-0.146% others

Gold alloys 2.9=1.553-0.023% silver-0.059% nickel+0.051% zinc+0.024% iron+0.030% mercury+0.020% rhenium

Gold alloys 2.10=1.589-0.025% silver-0.061% nickel+0.051% zinc+0.040% mercury+0.023% rhenium

Gold alloys 2.11=1.7189-0.030% silver-0.066% nickel+0.045% zinc+0.029% mercury

The first formula for gold alloys 2.1 expresses a mixture of gold with silver only. We found that the more gold used the less silver blended a little bit and vice versa. The second formula for gold alloy 2.2 is similar to gold alloy 2.1 and the second formula adds nickel in the same way as silver, namely reciprocity. The third formula is adding a few zincs to the second formula to make gold alloy formula 2.3 making it shinier. Amazingly, after model 3 or the formula of gold alloys 2.3, the mixtures are more complicated with plenty of metals. The fourth formula of gold alloy 2.4 has 10 metals with others. There are added more than 7 other metals in the formula of gold alloys 2.3 as follows: Copper, iron, mercury, palladium, manganese, rhenium, arsenic and others (tin and cadmium). For that reason, putting more than 7 metals in formula 2.3 into 3 previous kinds of metals generated new formula 2.4. The formula of gold alloy 2. 5 has almost the same amounts and kinds of metals in formula 2.4 whereas there are tiny differences in every column. The formula of gold alloys 2.6 and 2.7 are very similar in metal compositions. Both have no copper as formula 2.4 and 2.5. Formula 2.7 has no arsenic whilst formula 2.6 has that metalloid. Removing off some metals in the formula of gold alloys 2.8 as well as formula 2.9 are then almost the same. No matter if it is formula 2.8 or formula 2.9, there will be miscellaneous others included. Finally, the properties of formulas 2.10 and formula 2.11 look like the previous formulas. Moreover, the formula of gold alloy 2.10 also contains rhenium, neither is formula 2.11.

In summary, there are two secret formulas in the early Ayutthaya periods. One is formula 1.1 is a simple formula but the other formula 1.2 is very sophisticated due to plenty of metals dependent or inversely proportional to each other with gold. However, there are eleven secret formulas in the present market era. Likewise, they are three simple formulas comprising a fewer metal kind. The other formulas 2.4-2.11 are very complicated because a lot of metals vary or reciprocal each other with the gold. Rather, the ingredients of various formulas are for the beauty that captures the details of workpieces as created by the goldsmith through using such various formulas.

TABLE 7
ANOVA[a]

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	10.459	1	10.459	15.537	0.000[b]
	Residual	76.739	114	0.673		

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	Total	87.198	115			
	Regression	18.731	2	9.365	15.457	0.000[c]
	Residual	68.468	113	0.606		
2	Total	87.198	115			
	Regression	23.906	3	7.969	14.101	0.000[d]
	Residual	63.292	112	0.565		
3	Total	87.198	115			
	Regression	28.423	11	2.584	4.572	0.000[e]
	Residual	58.775	104	0.565		
4	Total	87.198	115			
	Regression	28.423	10	2.842	5.078	0.000[f]
	Residual	58.776	105	0.56		
5	Total	87.198	115			
	Regression	28.384	9	3.154	5.684	0.000[g]
	Residual	58.815	106	0.555		
6	Total	87.198	115			
	Regression	28.144	8	3.518	6.374	0.000[h]
	Residual	59.054	107	0.552		
7	Total	87.198	115			
	Regression	27.815	7	3.974	7.227	0.000[i]
	Residual	59.384	108	0.55		
8	Total	87.198	115			
	Regression	27.466	6	4.578	8.353	0.000[j]
	Residual	59.733	109	0.548		
9	Total	87.198	115			
	Regression	26.853	5	5.371	9.79	0.000[k]
	Residual	60.345	110	0.549		
10	Total	87.198	115			
	Regression	25.625	4	6.406	11.549	0.000[l]
	Residual	61.573	111	0.555		
11	Total	87.198	115			

Note: a: Dependent variable: Gold alloys; **b:** Predictors: (Constant), %silver; **c:** Predictors: (Constant), %silver, %nickel; **d:** Predictors: (Constant), %silver, %nickel, %zinc; **e:** Predictors: (Constant), %silver, %nickel, %zinc, %palladium, %arsenic, %rhenium, %others, %manganese, %iron, %copper, %mercury; **f:** Predictors: (Constant), %silver, %nickel, %zinc, %palladium, %arsenic, %rhenium, %others, %iron, %copper, %mercury; **g:** Predictors: (Constant), %silver, %nickel, %zinc, %palladium, %arsenic, %rhenium, %others, %iron, %mercury; **h:** Predictors: (Constant), %silver, %nickel, %zinc, %palladium, %rhenium, %others, %iron, %mercury; **i:** Predictors: (Constant), %silver, %nickel, %zinc, %rhenium, %others, %iron, %mercury; **j:** Predictors: (Constant), %silver, %nickel, %zinc, %rhenium, %iron, %mercury; **k:** Predictors: (Constant), %silver, %nickel, %zinc, %rhenium, %mercury; **l:** Predictors: (Constant), %silver, %nickel, %zinc, %mercury

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TABLE 8
COEFFICIENTS[a]

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.	Correlations		
		B	Std. error	Beta			Zero-order	Partial	Part
1	(Constant)	1.954	0.084		23.39	0			
	%silver	-0.04	0.01	-0.346	-3.942	0	-0.346	-0.346	-0.346
2	(Constant)	2.045	0.083		24.639	0			
	%silver	-0.043	0.01	-0.379	-4.517	0	-0.346	-0.391	-0.377
	%nickel	-0.063	0.017	-0.31	-3.695	0	-0.27	-0.328	-0.308
3	(Constant)	1.889	0.095		19.821	0			
	%silver	-0.037	0.009	-0.327	-3.954	0	-0.346	-0.35	-0.318
	%nickel	-0.074	0.017	-0.363	-4.382	0	-0.27	-0.383	-0.353
	%zinc	0.04	0.013	0.256	3.026	0.003	0.245	0.275	0.244
4	(Constant)	1.525	0.275		5.544	0			
	%silver	-0.023	0.013	-0.201	-1.82	0.072	-0.346	-0.176	-0.147
	%nickel	-0.058	0.02	-0.288	-2.904	0.004	-0.27	-0.274	-0.234
	%zinc	0.053	0.016	0.339	3.336	0.001	0.245	0.311	0.269
	%copper	0.002	0.007	0.031	0.264	0.792	0.062	0.026	0.021
	%iron	0.024	0.023	0.102	1.007	0.316	0.302	0.098	0.081
	%mercury	0.034	0.024	0.185	1.397	0.165	0.284	0.136	0.112
	%palladium	-0.021	0.032	-0.057	-0.665	0.508	-0.089	-0.065	-0.054
	%manganese	0.181	8.093	0.002	0.022	0.982	-0.088	0.002	0.002
	%rhenium	0.02	0.017	0.118	1.192	0.236	0.075	0.116	0.096
	%arsenic	-0.08	0.124	-0.053	-0.646	0.519	0.036	-0.063	-0.052
	%others	-0.146	0.187	-0.067	-0.782	0.436	0.028	-0.076	-0.063
5	(Constant)	1.525	0.274		5.573	0			
	%silver	-0.023	0.012	-0.2	-1.909	0.059	-0.346	-0.183	-0.153
	%nickel	-0.058	0.02	-0.288	-2.918	0.004	-0.27	-0.274	-0.234
	%zinc	0.053	0.016	0.339	3.386	0.001	0.245	0.314	0.271
	%copper	0.002	0.007	0.031	0.264	0.792	0.062	0.026	0.021
	%iron	0.024	0.023	0.102	1.012	0.314	0.302	0.098	0.081
	%mercury	0.034	0.024	0.185	1.405	0.163	0.284	0.136	0.113
	%palladium	-0.021	0.032	-0.057	-0.668	0.506	-0.089	-0.065	-0.054
	%rhenium	0.02	0.017	0.119	1.2	0.233	0.075	0.116	0.096
	%arsenic	-0.08	0.123	-0.053	-0.65	0.517	0.036	-0.063	-0.052
	%others	-0.147	0.186	-0.067	-0.788	0.432	0.028	-0.077	-0.063
6	(Constant)	1.582	0.169		9.377	0			
	%silver	-0.024	0.011	-0.211	-2.168	0.032	-0.346	-0.206	-0.173
	%nickel	-0.061	0.018	-0.3	-3.424	0.001	-0.27	-0.316	-0.273
	%zinc	0.054	0.015	0.346	3.605	0	0.245	0.33	0.288
	%iron	0.022	0.023	0.096	0.982	0.328	0.302	0.095	0.078
	%mercury	0.031	0.02	0.167	1.495	0.138	0.284	0.144	0.119
	%palladium	-0.024	0.031	-0.063	-0.771	0.442	-0.089	-0.075	-0.062

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	%rhenium	0.019	0.016	0.11	1.185	0.239	0.075	0.114	0.095
	%arsenic	-0.081	0.123	-0.054	-0.656	0.513	0.036	-0.064	-0.052
	%others	-0.142	0.184	-0.065	-0.769	0.444	0.028	-0.074	-0.061
	(Constant)	1.582	0.168		9.401	0			
	%silver	-0.024	0.011	-0.21	-2.165	0.033	-0.346	-0.205	-0.172
	%nickel	-0.06	0.018	-0.296	-3.397	0.001	-0.27	-0.312	-0.27
	%zinc	0.053	0.015	0.337	3.556	0.001	0.245	0.325	0.283
	%iron	0.023	0.023	0.099	1.019	0.311	0.302	0.098	0.081
	%mercury	0.029	0.02	0.16	1.445	0.151	0.284	0.138	0.115
	%palladium	-0.024	0.03	-0.063	-0.773	0.441	-0.089	-0.075	-0.062
	%rhenium	0.019	0.016	0.109	1.181	0.24	0.075	0.113	0.094
7	%others	-0.146	0.184	-0.067	-0.794	0.429	0.028	-0.077	-0.063
	(Constant)	1.553	0.164		9.482	0			
	%silver	-0.023	0.011	-0.199	-2.079	0.04	-0.346	-0.196	-0.165
	%nickel	-0.059	0.018	-0.291	-3.353	0.001	-0.27	-0.307	-0.266
	%zinc	0.054	0.015	0.346	3.682	0	0.245	0.334	0.292
	%iron	0.024	0.022	0.103	1.058	0.292	0.302	0.101	0.084
	%mercury	0.031	0.02	0.171	1.562	0.121	0.284	0.149	0.124
	%rhenium	0.02	0.016	0.117	1.273	0.206	0.075	0.122	0.101
8	%others	-0.146	0.183	-0.067	-0.796	0.427	0.028	-0.076	-0.063
	(Constant)	1.553	0.164		9.501	0			
	%silver	-0.023	0.011	-0.204	-2.142	0.034	-0.346	-0.201	-0.17
	%nickel	-0.059	0.018	-0.289	-3.342	0.001	-0.27	-0.305	-0.265
	%zinc	0.051	0.014	0.323	3.615	0	0.245	0.327	0.287
	%iron	0.024	0.022	0.103	1.057	0.293	0.302	0.101	0.084
	%mercury	0.03	0.02	0.165	1.513	0.133	0.284	0.143	0.12
9	%rhenium	0.02	0.016	0.116	1.271	0.206	0.075	0.121	0.101
	(Constant)	1.589	0.16		9.919	0			
	%silver	-0.025	0.011	-0.215	-2.273	0.025	-0.346	-0.212	-0.18
	%nickel	-0.061	0.017	-0.301	-3.506	0.001	-0.27	-0.317	-0.278
	%zinc	0.051	0.014	0.327	3.656	0	0.245	0.329	0.29
	%mercury	0.04	0.018	0.217	2.219	0.029	0.284	0.207	0.176
10	%rhenium	0.023	0.015	0.135	1.496	0.137	0.075	0.141	0.119
	(Constant)	1.718	0.135		12.681	0			
	%silver	-0.03	0.01	-0.264	-2.954	0.004	-0.346	-0.27	-0.236
	%nickel	-0.066	0.017	-0.323	-3.8	0	-0.27	-0.339	-0.303
	%zinc	0.045	0.013	0.285	3.337	0.001	0.245	0.302	0.266
11	%mercury	0.029	0.017	0.159	1.76	0.081	0.284	0.165	0.14
Note: a: Dependent variable: Gold alloys									

Accordingly, we found that the formulas of gold alloys have entirely 13 formulas divided into 2 time periods: The early Ayutthaya age and the present market era. Surprisingly, we have the initial or fundamental ingredients of the two eras in the domain of common metals for making gold alloys. They may be picked up for some metal for mixing items into gold alloys by versed and professional goldsmith's desire to become a specific formula. Each formula is kept to be a qualified workpiece to be a secret

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formula. Fortunately, we know all the formulas from the sample we have, no matter how they were composed or fused to form gold alloys. Nevertheless, we found that at least 5 metals always made gold alloys different during the eras (Table 9): Silver, nickel, iron, mercury as well as rhenium and all five metals usually correlate with gold. Other metals were also blended in gold alloys to garnish special Thai goldware.

TABLE 9
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

DISCUSSION

The discovery of the answer was found in people of the same descent located in the original area. Thai gold alloys are made with only 11 important metals, which may seem complicated compared to the current gold alloy formulas. They contain 11 formulas in present Thai gold alloys making for Thai goldware. Thai gold alloys from the early Ayutthaya period will only have 2 formulas but one of two much more complicated components than all current Thai gold alloys and possibly more sophisticated than gold alloys 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 look more complicated because many kinds of metals are used in the mixture and these mixtures vary dependently and inversely correlate with gold. 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 alloys in the modern day. This is because the craftsman may not have been aware of the ingredients of Thai goldware from ancient times that were kept as a secret formula. Meanwhile, modern gold alloys use 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, that is why the use of gold alloys has many formulas of gold alloys to differentiate more styles. Recognizing the ingredients in gold alloy formulas for making Thai goldware makes you realize that the current goldsmith's concept is different from what is called “art” by creating various formulas in acquiring Thai goldware at present. If they are the workpieces 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 gold alloys from ancient times that had never been revealed.

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Meanwhile, goldware nowadays looks too industrial (Hiskey, 1988 & Atluri, 1988). It shows that Thai gold alloys in the present era have less gold mixed whereas there is an unnoticeable difference. Consumers do not realize that the average quality of goldware today has slightly decreased.

CONCLUSION

When analyzing with a statistical model of multiple regressions *via* the stepwise method we found the answer as follows: The gold alloys in the early Ayutthaya periods averaged 15.54 K more than 14.72 K of gold alloys these days. It can be said that traditional gold alloys are averaged better a little bit than gold alloys in marketing today. We found that there have never disclosed two secret formulas for making gold alloys in those days, meanwhile making gold alloys is 11 formulas in these days. In the early Ayutthaya periods, one is a simple formula but the other formula is very sophisticated due to plenty of metals correlating by corresponding or converting each other with gold. However, there are eleven formulas in the present market era. Likewise, they are three simple formulas comprising a few metals. The other formulas are more complicated since a large number of metals correspondingly and inversely with gold. Rather, the ingredients of various formulas are so elegant that capture the details of workpieces as created by the goldsmith through using such various gold alloy formulas. Fortunately, we have perceived all the formulas from the research. Nevertheless, we found that at least 5 metals always made gold alloys different during the eras and all five metals usually correlate with gold. Other metals might also blend in gold alloys to garnish special Thai goldware.

RECOMMENDATIONS

- This research reveals the ingredients of gold alloys in terms of gold alloy formulas both in the past and in the present times that the goldsmiths kept secret. Its findings make it possible to continue to create Thai goldware as 600 years ago. This research also makes it possible to develop the ingredients of the formula for making goldware in the past and apply it to the current-work to make the color of gold bright and radiant for a long time.

- Knowing the percentage of metal elements used in mixing gold alloys, allows us to estimate the amount and the number of metal types used appropriately for each type of goldwork.

- The average amount of gold used by goldsmiths in workpieces from the early Ayutthaya period was 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.

- 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 bought many amulets found in the crypt that the government 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 gold alloys. This matter is something worth studying further. Even if there is a misfortune that destroys life getting to the point of being viewed as a superstition. However, fortunately, the traditional gold alloy formula has made goldware not change so 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 non-toxic metals from our old knowledge to replace them.

- Mixing metal elements of Thai gold alloys in the current marketing era is produced for

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competition and cost reduction. Therefore, a mixture of a smaller number of gold elements is not only used but there are also generating various gold alloy formulas. In addition to decorated with gems and modern technology that will make Thai goldware sustainable and popular. However, the ingredients of Thai gold alloys 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 gold alloy formulas and how much they will help further the development of Thai goldware in the present era.

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