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Identification of the country of origin of duvets by PIXE

T. Yamada
Department of Medical Innovation, Osaka University Hospital, Osaka 565-0871, Japan
tomomi.yamada@dmi.med.osaka-u.ac.jp

K. Kataoka
SB Works Co. Ltd., Yokohama 236-0004, Japan

T. Saunders
Nagasaki University Graduate School of Medicine, Nagasaki 852-8521, Japan

K. Sera
Iwate Medical University, Iwate 020-0603, Japan

T. Takatsuji and T. Nakamura
Nagasaki University Graduate School of Environmental Studies, Nagasaki 852-8521, Japan

Y. Nose
Kyushu University Graduate School of Medicine, Fukuoka 812-8582, Japan

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The objective of this study is to examine the ability of PIXE to distinguish the country of origin of duvets. The stable isotope method that is currently used is not recognized as reliable. Mineral concentrations of down feathers from France, Poland and Taiwan were measured by PIXE. The measurements were statistically analyzed. The results show even a scatter plot of appropriately chosen minerals distinguished between those countries at 95% accuracy.

Keywords: PIXE; Duvet; down; feather; mineral; element; statistical analysis; country of origin.

1. Introduction

The Japan Feather Products Cooperative Association (JFPCA) sent its member companies a warning that even though most comforters in Japan are sold as being produced in Europe, most of the down in those duvets was of falsified origin. According to the statistics for 2014, 72% of feathers came from China or Taiwan and only 14% from France or Poland. On the other hand, 97% of down feather products sold in Japan is designated as being produced in Europe. These figures clearly contradict each other. The major reason for this falsification is the inability to scientifically confirm where the feathers were actually produced. This allows makers to insist whatever they like without fear of lawsuits.

The objective of this study is to examine the ability of PIXE in verifying the origins of feathers. We previously published a study to predict the risk of atopic dermatitis in infants using hair minerals measured by PIXE.[1] This experience suggests that PIXE may be also useful in predicting the origin of feathers.

Firstly, it should be noted that "down" is different from "feathers" and has superior qualities for duvet manufacture. Down is a fine layer of fluffy, spherical feathers which are soft and light and have excellent insulation properties. It is usually plucked from the belly of the bird. Unlike down, feathers are larger, heavier and flat, so more of them are needed to provide the same insulation. Secondly, in the Japanese market, European down is preferred over Chinese down. The feeding period in France for foie gras is about three times longer than that in China for Peking ducks. This allows the geese to mature longer. In general, feathers produced in China are inferior to those from Europe in terms of resilience and heat-retention.

A stable isotope technique has been used to confirm the origin of down feathers. A bird's feather is mainly composed of protein (keratin), which is built out of amino acids, which in turn mainly consists of the elements carbon (C), hydrogen (H), nitrogen (N) and oxygen (O). The stable isotope technique uses these four elements and has been used to identify migratory bird breeding areas.[2–7] Last year, however, Werner *et al.*[2] pointed out the unreliability of the isotope technique even for migratory birds. The main reason why the stable isotope technique is not very reliable is that it uses only the four major elements and the variation in samples is not taken into consideration[2] despite very small difference between reference and sample values. Identifying the breeding country of down producing birds is far more complicated, since feathers from different areas are usually mixed in a comforter.

In July 2016, the JFPCA sent us some down samples from various countries. This paper describes the results obtained from PIXE analysis of these samples.

2. Methods

2.1. *PIXE analysis*

Figure 1 shows four down samples provided by the JFPCA that came from two areas (central and southern parts) in France and one each in Poland and Taiwan.

Fig. 1. Down samples provided from JFPCA for PIXE analysis.

80 down balls were randomly chosen from the sample of each area and mineral concentrations were measured using PIXE.

Since JFPCA did not provide us with sample of down from China, we purchased a cheap one with no origin designated on the open market, hereafter referred to as China-x.

2.2. *Statistical analysis*

First, a stepwise logistic regression analysis was applied to obtain best combinations of minerals in order to accomplish optima accuracy in distinguishing the areas. The analysis resulted in an optimal linear discriminant function. A scatter plot between two most efficient minerals was obtained to illustrate their distinguishing ability between the areas of origin. All mineral measurements were transformed to natural logarithms.

Figure 2(a) is a scatter plot for manganese and calcium where both variables are log-transformed. It appears France and Taiwan are nearly perfectly separated by a linear function. Figure 2(b) shows the predicted probability taken from France; upper for downs from France and lower for those from Taiwan.

3. Results and Discussion

An optimal linear discriminant function was

$$S = -106 - 1.2 \ln \mathrm{Mg} + 1.53 \ln \mathrm{Si} + 19.4 \ln \mathrm{Ca} - 23.2 \ln \mathrm{Mn}\,.$$

For a down ball whose mineral measurements equal $\ln \mathrm{Mg} = a, \ln \mathrm{Si} = b, \ln \mathrm{Ca} = c, \ln \mathrm{Mn} = d$, the probability of being taken from the sample of France is predicted by

$$P = \exp(S)/(1 + \exp(S)),\ \text{where } S = -106 - 1.2a + 1.53b + 19.4c - 23.2d\,.$$

Figure 2(b) shows histograms of P for the sample of each country. Take $P = 0.7$ as a cutpoint, then only 6 in France were incorrect. Thus, an overall correct prediction is $234/240 = 0.98$.

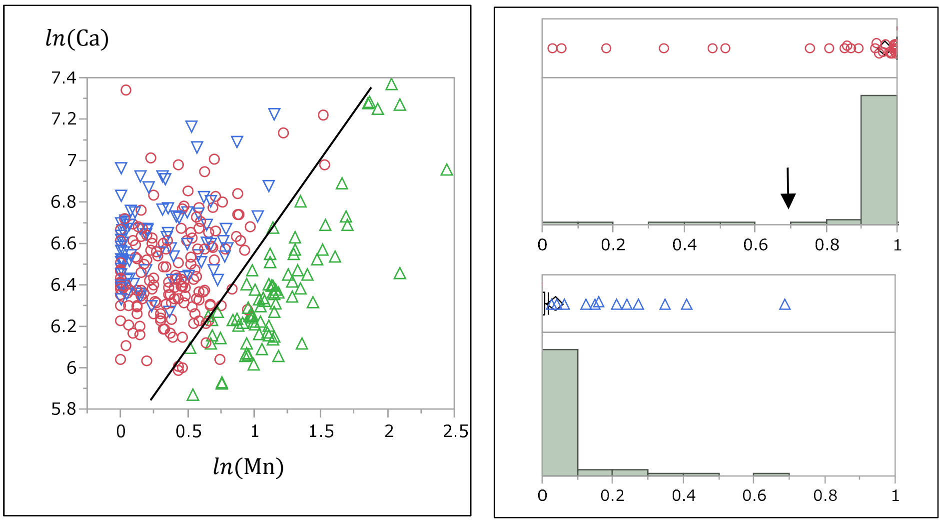

Fig. 2. (a) France ○, Poland ▽ vs Taiwan △ (b) Predicted probability of taken from France.

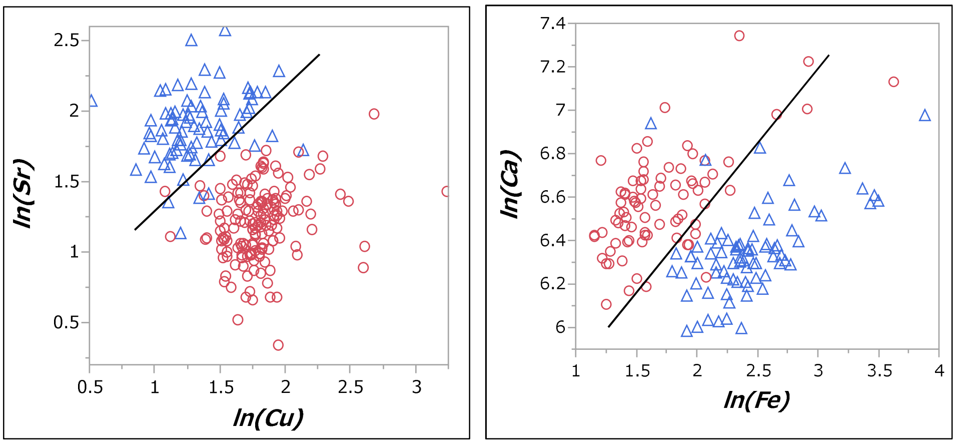

Fig. 3. (a) France ○ vs Poland △ (b) Central France ○ vs Southern France △.

Figure 3(a) is a scatter plot between copper and strontium for the two samples from France and one from Poland. Again, France and Poland appear nearly perfectly distinguished. Figure 3(b) shows a scatter plot between iron and calcium for Central France, and Southern France. Two samples from France are also nearly perfectly distinguished by a straight line, or statistically a linear discriminant function.

Figure 4(a) is a scatter plot between Si and Cu for Europe (two samples from France and one from Poland) and China-x. Europe and China-x are nearly perfectly distinguished by a straight line. As shown in Fig. 4(b), Taiwan is distributed like Europe in the scatter plot between Si and Cu.

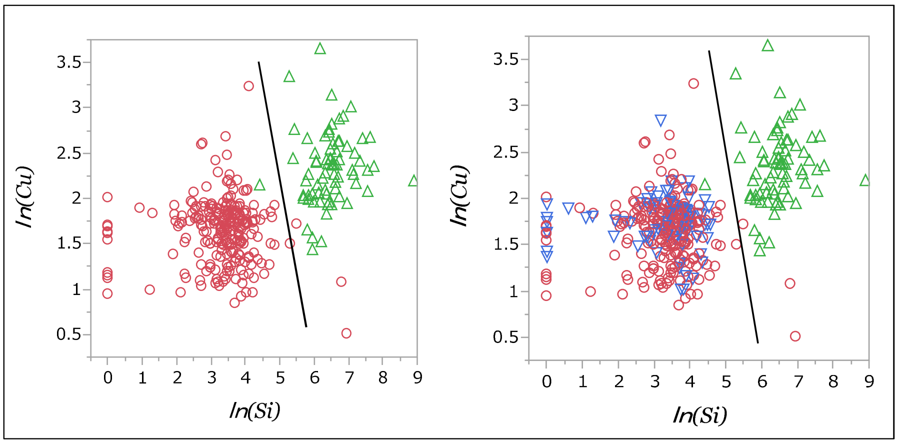

Fig. 4. (a) France ○, Poland ○ vs China-x △ (b) added Taiwan ▽

In summary, given any two areas, a scatter plot between appropriate elements can distinguish between the areas at about 95% accuracy. Adding a few elements improved the accuracy.

4. Conclusion

Mineral concentrations of down are strikingly different in different areas, suggesting that food and environment play a major role in determining the mineral content of water fowl down. If random samples of down are obtained from different countries, a PIXE-based analysis of appropriately chosen elements should be able to distinguish between countries or even between different regions in the same country.

Although the sample used in the present study were not random samples, the results are encouraging. As a next step, we plan to collect random samples from some European countries and China and to determine optimal combinations of minerals to distinguish between the countries in order to eradicate falsification in the country of origin claims.

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References

1. T. Yamada, T. Saunders, S. Kuroda, K. Sera, T. Nakamura, T. Takatsuji and Y. Nose, Cohort study for prevention of atopic dermatitis using hair mineral contents, *J. Trace Elem. Med. Biol.* **27** (2013) 126–131.
2. S. Werner, K. Hobson, S. Wilgenburg and J. Fischer, Multi-isotopic (δ^2H, δ^{13}C, δ^{15}N) tracing of molt origin for red-winged blackbirds associated with agro-ecosystems, *Plos One* **11** (2016) e0165996.

3. A. Roberts and M. Conover, Breeding origins of northern shovelers (anas clypeata), *Wilson J. Ornithol.* **127** (2015) 233–238.
4. R. Hood-Nowotny and B. Knols, Stable isotope methods in biological and ecological studies of arthropods, *Entomol. Exp. Appl.* **124** (2007) 3–16.
5. D. Thompson, S. Bury, K. Hobson, L. Wassenaar and J. Shannon, Stable isotopes in ecological studies, *Oecologia* **144** (2005) 517–519.
6. M. Wunder, C. Kester, F. Knopf and R. Rye, A test of geographic assignment using isotope tracers in feathers of known origin, *Oecologia* **144** (2005) 607–617.
7. Y. Cherel, K. Hobson and H. Weimerskirch, Using stable-isotope analysis of feathers to distinguish moulting and breeding origins of seabirds, *Oecologia* **122** (2000) 155–162.