# Indigo Dyeing and Fermentation
# Sukumo, Essential for Traditional Japanese Aizome

## Teinture et fermentation Sukumo de l'indigo, essentiel pour la méthode japonaise traditionnelle de coloration « Aizome »

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**ABSTRACT.** Aizome, or indigo dyeing, is one of Japan's traditional dyeing methods. The dye required for this indigo dyeing process is produced by microbial reactions. In Japan, artisans called "aishi" are responsible for the production of this fermentation product, called sukumo, which is necessary for indigo dyeing. The production of sukumo has long relied on the experience and intuition of these craftsmen, but in recent years microbiological analysis has been introduced. This column gives an overview of the sukumo production process, which is not yet fully understood scientifically, and presents the fact that the ancient Japanese fermentation technique has found its way not only into the food and pharmaceutical industries, but also into the fields of dyeing and fashion.
**KEYWORDS.** Indigo, Sukumo, Dyeing method, Aizome, Fermentation, Tadeai, Japan’s tradition.

### Introduction

There is a tradition, that states the name "Japan Blue" was originally coined by Robert William Atkinson, an English chemist in the Meiji era, who was impressed by the blue colour produced by indigo dyeing in Japan. Aizome is a traditional dyeing of natural indigo and this dyeing method uses a unique mechanism of microbial reaction to produce colour.

Sukumo is a fermentation product of the indigo plant, Tadeai (*Polygonum tinctorium*), which is essential for this authentic indigo dyeing. Less information is available about sukumo, although it is the raw material for the indigo dyeing solution. Tokushima Prefecture of Japan has become a sacred place for a series of indigo dyeing techniques known as Awa-ai [1]. The artisans known as "aishi" or indigo masters produce the sukumo using one of the oldest traditional techniques in Japan, which has been practised for 600 years.

Dyeing is only indirectly related to artistic creation. However, aizome has been used in various artistic objects and creations. Shibori, for example, is a traditional Japanese dyeing technique in which fabric is manipulated to create patterns using dyes. The fabric is folded, twisted, or tied in various ways before being dyed, resulting in unique and intricate patterns. This type of dyeing technique has been used to create a wide range of artistic objects, including clothing, tapestries, and wall hangings, and has been adapted and modified over time to create new and innovative works of art [2].

Until now, little was known about the involvement of microorganisms in the sukumo production process. The authors have conducted interviews with various experts, including the aishi and the dyer called “someshi”, and investigated the role of microorganisms in the sukumo production process, with the aim of gaining knowledge of the reactions that occur in the overall process and how they relate to the indigo dyeing. As a scientist, it is our desire to clarify unknown events and pass them on to future generations, and as a Japanese, we wanted to contribute to the further development of their unique culture in Japan.

 

## Principles of traditional Japanese indigo dyeing

The microbial reaction involved in this indigo dyeing process is quite simple. The indigo dye is applied to the fabrics using an indigo solution made from sukumo, ash and natural organic materials such as Japanese sake and wheat bran, which activates the microorganisms and creates a reducing state by oxidizing the organic materials and an anaerobic state is created, i.e., a state in which there is no oxygen. More specifically, the original component of indigo called indican (indoxyl β-D-glucoside) which is found in the tadeai leaf exists as a precursor to indigo. When the leaves are decomposed, the enzyme (β-glucosidase) contained in the leaves acts on this indican, cleaving the glucose and producing indoxyl which is immediately oxidized to indigo. Indigo is normally insoluble in water, but addition of ash creates alkaline conditions with a pH around 10, which is high enough to leach leuco-indigo into the solution [3]. The indican or leuco-indigo will eventually adhere to the fabric and cause it to develop colour. Leuco-indigo is normally colourless (light yellow to brown), but when exposed to oxygen, it turns into indigo. After soaking the fabric in the indigo solution, the dyer takes it out from the bottle and expose it to air, which oxidises the leuco-indigo and produces the indigo colour. The indigo produced remains and is fixed to the fabric because it is insoluble, as mentioned above (Figure 1).

**Figure 1.** *Fabrics dyed with aizome (at Watanabe's, Tokushima)*

Indigo cannot be used for direct dyeing by dissolving it in water as it is insoluble in water. Indican and indoxy, however are water soluble, so that those can penetrate the fibres and oxidise inside the fibres to form indigo, i.e. they can be dyed. Therefore, this dyeing with fresh leaves can only be done when and where they are available and can only be dyed thinly. Another key point is that leuco-indigo can be adsorbed on ionic, protein-based fibres (e.g. silk and wool), but its adsorption on plant fibres such as cellulose-based materials, is weak. It is therefore difficult to stain cotton. The reduced form of indigo is water soluble. It can be reduced by microbial fermentation or by adding of a chemical reducing agent such as sodium hydrosulfite to convert the indigo to a water-soluble leuco form, which can then be soaked into the fibres. Leaching insoluble indigo from tadeai leaves and making it dyeable is called 'indigo building', and is referred to as 'fermentative building' when done by fermentation and 'chemical building' if done by chemical means. In the fermentation process, microorganisms active in the special alkaline environment are involved in the reduction of indigo. Naturally, this method does not require chemical reducing agents and is environmentally friendly.

## A material called sukumo made by artisans

What struck us throughout our research into the sukumo production process was that the number of people involved in making sukumo is already small and, as with other Japanese crafts, the volume of sukumo production itself is declining due to a lack of successors to pass on the technique. While the popularity of indigo dyeing itself is increasing slightly, the supply of the raw material used to make it is not keeping up with the demand. There are currently, only 5 sukumo manufacturing factories in Tokushima Prefecture, and only a few artists and dyers who prefer to use natural indigo instead of using chemical dyes are able to obtain supplies of sukumo. It is human nature to want to analyse the details of this sukumo production process in order to produce sukumo more easily and in larger quantities, just as we do with other industrial products. If the cost can be reduced, it can be industrialized.

The process of making sukumo is similar to the process of making compost from food waste or livestock waste such as cattle dung, known as composting [4]. In other words, the organic matter and toxic substances contained in the waste are oxidised and decomposed to reduce their volume by reacting with the oxygen in the air, and nitrate, phosphate and other minerals, which are the source of fertiliser, are concentrated in the process. On the other hand, the materials used in the production of sukumo are only tadeai leaves and water, and through the process of turning the leaves back and forth in contact with air for about 120 days, the indigo and the microorganisms necessary for the dyeing process are extracted and combined into a set as sukumo (Figure 2 and 3). What happens during this four-months process of bedding (Nesekomi in Japanese)? The indigo masters, aishi, skilfully manage this process by communicating with the microorganisms.

Tadeai, an annual grass used as a raw material, is sown in early spring and harvested in the summer and autumn. After sun drying, the leaves are sorted, and the process of making sukumo begins on the first day of early October, which is the first auspicious day of the month of Daian in the Japanese calendar. The leaves are spread out on a straw mat and repeatedly watered and mixed. This process is rigorously repeated to ensure that the water and leaves are mixed without any unevenness. This process is repeated while checking the smell and the visual observation to confirm the decomposition of the leaves. During this process, organic matter contained in the leaves is oxidised and the indigo is concentrated by reacting with the air through regular stirring. This process continues for about 120 days, until the end of February. During this period, the decomposition of the tadeai leaves causes the temperature to rise to around 70°C, and the smell of organic acids and ammonia fills the air, increasing with each passing day.

According to the aishi when this smell disappears, it is a signal that the sukumo making is complete. This simply rely on their long experience and faithfully follow the teachings of their predecessors. They have never tried to simplify the process, wondering if it could be completed in less time. In mid-winter, the water in this season is finally poured over the top. This may be because the water in this cold season is less susceptible to spoilage from contaminated bacteria in the cold season.

The dyers and dyeing artists wait for the process to be completed and then begin the dyeing for the year. In March, the aishi begin sowing the tadeai again, and a new year of sukumo production begins. It is clearly a vintage, just like the routine of making wine and sake.

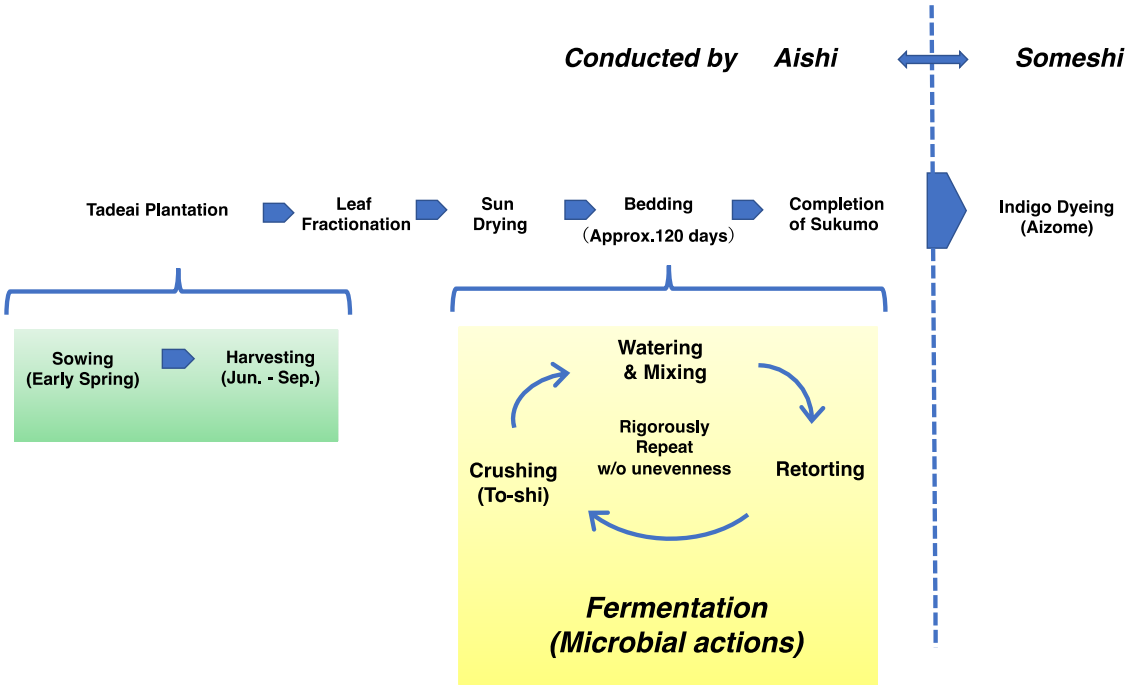


**Figure 2.** *Production of sukumo in overall indigo-dyeing process.*

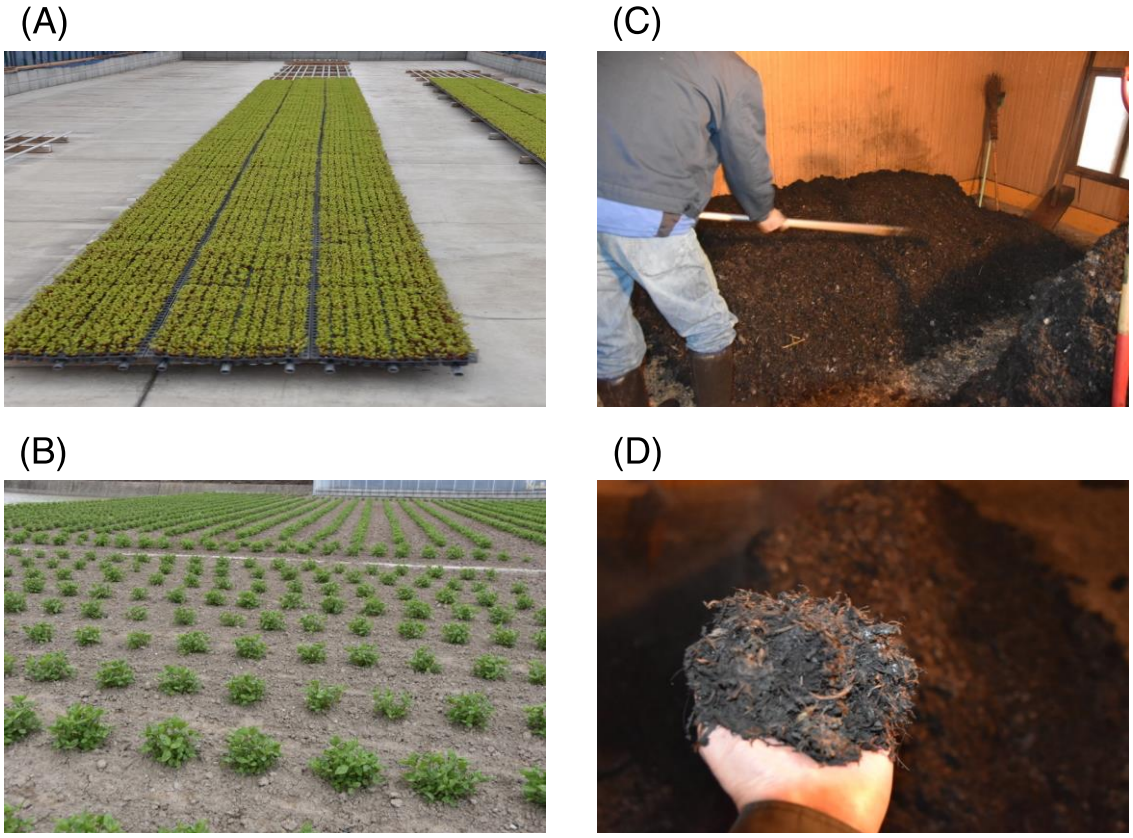


**Figure 3.** *Pictures,(A) Seeding of Tadeai; (B) Plantation; (C) Retorting; (D) Sukumo being fermented.(Photos are taken at Aiya Terroir and Nii seiaisyo)*

## Microbiology of sukumo fermentation

In aizome, the processes of making the sukumo and dyeing by the dyer are separated according to their specialisation, and resulting in a division of labour. There were also specialised traders called “aishou”, the indigo dealers. The overview described so far focuses only on the production process of sukumo. During the dyeing process, someshi skillfully handles the indigo solution added with sukumo and dyes the fabrics.

Several indigo-reducing bacteria, a microorganism indispensable to the indigo dyeing process have been iidentified from the indigo dyeing solution and their physiological properties and behaviour in the production process have been studied [5, 6]. We have also tried molecular analysis of their existence in the process of sukumo production. The results showed that the indigo-reducing bacteria were not present at the beginning of the sukumo production process and were not detected until about two months after the bedding process had been completed. In other words, the bacteria did not appear untill the bedding process had been continued for two months. As this type of microorganisms prefers alkalinity, it is likely that it appears when the leaves decompose to some extent and the ammonia produced in the process makes the environment alkaline. So, is indigo dyeing possible in the presence of this indigo-reducing microorganism? Indican and indoxil, the precursor of indigo, are known to be present in indigo leaves. If so, would indigo dyeing be possible with the presence of only these bacteria and indigo leaves? The answer was no from our experiments. However, the leaves were decomposed to some extent and, after a certain period of time, no colour developed even when the indigo-reducing bacteria were present. What exactly is happening in this process? The process of indigo leaf fermentation involves a variety of microorganisms in the reaction, not just the decomposition of leaf, the establishment of an alkaline condition and the extraction of indigo. The details of this process are currently being researched, but there should be a scientific basis for sukumo production, which takes an indigo master about four months to complete. The craftsmanship passed down from generation to generation, and the production of sukumo based on the artisan's sense of smell and feeling, is beginning to be supported by scientific evidence.

## Sukumo production is also a traditional Japanese fermentation

Fermentation is scientifically defined as microbial metabolism and functions that can be used for material production. The Japanese culture of fermentation has taken root not only in the food and pharmaceutical industries [7-9], represented by miso, soy sauce, Japanese sake, and antibiotics, but also in the traditional clothing and fashion industries where aizome is incorporated as another example of fermentation technology in Japan.

Alcoholic bevarages such as sake and wine have a long history in human society and civilisation. It dates back to B.C. However, it is only in the last hundred years that it has become clear that alcoholic fermentation is carried out by microorganisms. The Dutch scientist Antony van Leeuwenhoek discovered yeast some 300 years ago, and it was only a little over 100 years ago that the French scientist Louis Pasteur discovered that yeast was involved in alcoholic fermentation. Since then, microbiology has made many breakthroughs and developments in human society. Before these discoveries, however, people had been enjoying alcoholic beverages produced by microorganisms for thousands of years. People simply took advantage of the reactions of microorganisms without knowing their names or functions. Alcoholic fermentation has been revealed not only the microbial physiology and biochemistry of yeast, but also the metabolism involved in the expression of flavour and aroma in the brewing process. There was a time in the past when sake brewing was done without knowing the principles and by praying to God, but nowadays, part of the sake brewing process has been managed by controlling reactions using AI.

The same idea could be applied to the natural indigo dyeing of Aizome. Microbiological research on the indigo dyeing process may still be in its infancy. It remains to be seen to what extent microbiologist will unravel the mysteries of microorganisms involved in the production of sukumo and aizome. And there must be a long way to go before the full picture is revealed. We hope that the day is not far off when future research will contribute to this traditional Japanese dyeing and other forms of art and fashion.

## Concluding remarks

As attention to traditional Japanese culture and practice, as represented by Japan-Blue and Cool-Japan [10], gains worldwide popularity, interest in indigo dyeing of aizome is also increasing. Young people with a high artistic sensibility are particularly concerned with originality, and are interested in various attempts to incorporate aizome not only into traditional Japanese clothing such as tenugui hand towels and happi coats, but also into modern fashion such as jeans, T-shirts, scarves, and mufflers. There is also a growing number of people who want to make their own sukumo because of the shortage of supply, and who are now involved in the entire process from the production of sukumo to the indigo dyeing of aizome.

In the field of dyeing, artists and scientists have worked together to develop new techniques and materials. This collaboration has led to the creation of new and innovative works of art. Artists have used dyeing techniques as a means of expression in paintings and textile works. The colours and patterns created by dyeing can add a unique beauty and depth to a work of art, and are therefore the most important source of originality in art.

The microorganisms play the leading role in the fermentation process, and we humans are the directors or producers who are allowed to benefit from their work. This may sound like a bit of an offensive, as microorganisms have been living normally for billions of years, and we are just newcomers who appeared on Earth only a few million years ago. Humans continue to enjoy a quality of life thanks to the benefits of microorganisms. And we can contribute to the creation of a more sustainable and valuable society by understanding traditional cultures based on science.

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