HAMK
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of Applied Sciences

LASER CUT PLYWOOD KEY HOLDER DESIGN AND PROTOTYPE

with optional natural dye version

Bachelor's thesis
Smart and Sustainable Design
Spring 2024
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Smart and Sustainable Design — Tiivistelmä
Tekijä Jussi Suvela — Vuosi 2024
Työn nimi Vanerista laserleikatun avainnaulakon suunnittelu ja prototyyppi luonnonvärjätyllä vaihtoehdolla
Ohjaaja Helena Leppänen, Auli Rautiainen

Opinnäytetyön tavoitteena oli suunnitella ja tuottaa avainnaulakon prototyyppi asiakkaalle, Papurino Oy:lle. Prototyyppi toteutettiin koivuvanerista laserleikkaustekniikkaa hyödyntäen. Sen suunnittelussa otettiin huomioon pientuottaminen ja sopivuus asiakkaan tuotekatalogiin. Prototyypistä tehtiin myös värillinen, luonnonväreillä pintakäsitelty versio. Tuoteidea pohjaa länsimaisiin tarinoihin varastelevasta harakasta.

Tutkimuksellinen tausta-aineisto kerättiin verkkosivustoilta sekä kirjallisuudesta. Tarinoita varastelevasta harakasta saatiin kasaan usealta vuosikymmeneltä. Prototyypin toimivuuden tiedonhakumenetelmänä käytettiin havainnointia ja testausta. Käytännön testauksessa selvitettiin millaiset koukut sopivat naulakkoon ja miten luonnonvärit sopivat käytettäväksi koivuvanerin pinnassa. Luonnonvärejä testattiin kolme: indigo, biohiili ja kuusi.

Opinnäytetyön tuloksena syntyi kansantarinoista inspiraationsa saanut laserleikattu prototyyppi, josta on kaksi versiota: käsittelemätön ja luonnonväreillä pintakäsitelty. Tuotteelle luotiin oma tarina ja sen lyhennelmä. Luonnonvärien valonkestotesti osoitti niiden soveltuvan, vesiliukoiseen petsiin sekoitettuna, käytettäväksi koivuvanerin pinnalla. Valonkesto sisätiloissa haalistumattomana todettiin olevan vähintään 15 vuotta.

Avainsanat Laserleikkaus, vaneri, käyttöesine, tarinallistaminen, luonnonväri.
Sivut 35 sivua

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Smart and Sustainable Design — Abstract
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Subject Laser cut plywood key holder design and prototype with optional natural dye version
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The aim of the thesis was to design and produce a prototype of a key holder for the client, Papurino Oy. The prototype was produced using birch plywood and laser cutting technology. It was designed for small-scale production and it had to fit into client's product catalog. Additionally, a colored version of the prototype was created with natural dye application. The product concept was based on Western tales of a thieving magpie.

The research background material was gathered from websites and literature. Stories of the thieving magpie was collected from several decades. Observation and testing were employed as methods of assessing the functionality of the prototype. Practical testing was conducted to determine the suitable hooks for the holder and how natural dyes performed on the surface of birch plywood. Three natural dyes were tested: indigo, biochar and spruce.

As a result of this thesis, two versions of the laser-cut prototype inspired by folktales was produced. One untreated and one with natural dyes. A short story was crafted for the product along with its product description. The lightfastness test of the natural dyes confirmed their suitability for use on birch plywood surfaces when mixed with water-soluble stain. Lightfastness test validated that the tested colors will remain unfaded indoors for at least 15 years.

Keywords Laser cutting, plywood, functional item, storytelling, natural dye.
Pages 35 pages

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1 Introduction

The goal of this thesis is to develop a prototype of a functional item for the client, Papurino Oy. Choice of the topic arises from both the client's needs and designer's own professional growth. The designer has previously designed several decorative items using plywood with good success. Some of them are sold at Finnish design stores. With this thesis, designer's aim is to further enhance his design skills in creating functional items. Moreover, this project aligns with the client's request to diversify their product catalogue. The designer will propose the product idea and develop a story to accompany it. He will create personas for the client's target group utilizing information gathered from the client and their webpages.

First part of the thesis introduces the client and focuses on designing the wall-mounted key holder. It consists of back plate, key hooks and decorative elements. Inspiration for the overall design stems from widely held belief in the Western world that magpies steal shiny things and stash them in their nests. The concept is to portray a magpie that has gathered numerous shiny keys and stored them in its nest.

Second part of the thesis consists of testing the usability of natural dye application on birch plywood. Three different color sources and two solvents will be tested. Colorants have been extracted and processed to powder at Hamk Tech Laboratories. Test pieces with natural dye application will undergo a lightfastness test, followed by an analysis of the results. Finally, a colored version of prototype will be created.

The Designer will utilize the knowledge gained from his studies and previous commissions involving laser cutting technique. Studies include: Introduction to Laser Cutting, Digital Tools, Digital Surface Design, Collaboration Project, Smart and Sustainable Research and Work Placement. The combined studies and commissions amount to 44 study points, equivalent of 1188 hours of work.

1.1 Goals, result and scope

The goal of this thesis is to produce a prototype of laser cut plywood key holder for a client that can be commercialized for small-scale production. There will be two versions of the prototype: one untreated and one with natural dye application. Dyes will undergo a lightfastness test to determine the suitability of the natural dye for a functional item.

From a sustainable standpoint, a untreated version is more ecological and economical while applying natural dye provides an option to make more colorful and unique item. Colorants and stains used in dyeing adds more costs, while non-dyed is mono material and more ecological but might not be as marketable. These factors will influence the pricing of the product, and is there a market for both options. Ultimately, the decision whether to produce a untreated or colored version, or both will be left to the client.

This thesis includes product ideation, crafting a story to accompany it, designing and producing a prototype. It also involves conducting a lightfastness test of selected natural colorants. Thesis does not delve into extensive natural color testing, examination of the chemical processes, or analysis of the cost structures.

1.2 Problems and methods of solving them

Main question is:

”What is the prototype of the key holder designed for a laser cutter for Papurino Oy like?”

Sub-questions are:

”How can a compelling story be created for a product?”

”What does product with implemented folklore look like?”

”Is water-based or stain-based natural dye durable on birch plywood product?”

Main question will be answered acquiring information through own practical process and observation. Design process will include market research, sketching using double diamond method, observation and testing.

Sub-questions one and two will be answered collecting data online and through physical books. Acquired data will be utilized in the design process and story crafting. Last question will be answered conducting a lightfastness test and analyzing the result.

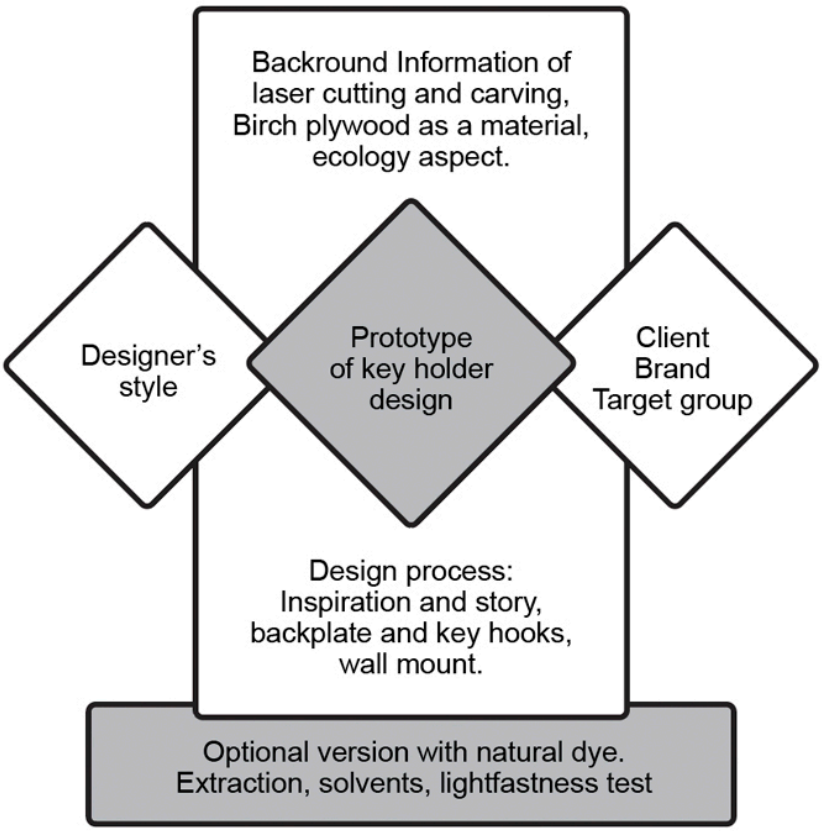
1.3 Frame of reference

Aim of the thesis is to design a prototype of wall mount key holder for a client. Frame of reference is presented as a shapes of plywood boards (figure 1). Designer will use his own visual style accordingly to produce a product that fits into client's brand and target group. Designer will use his previous knowledge that he has acquired from laser cutting studies, work experience and bibliography. He will take ecology aspect into an account.

Design process involves collecting inspirational folklore and fictional stories centered around thieving magpie. They serve as a foundation for the design. Different wall mount options will considered.

Last part, which is not included as client work but is optional for them to use, is to test natural dye application on the designed product. This part will include extraction of the ingredients, testing two solvents and conducting a lightfastness test which will show if natural dye application is a suitable on birch plywood or if further development is necessary.

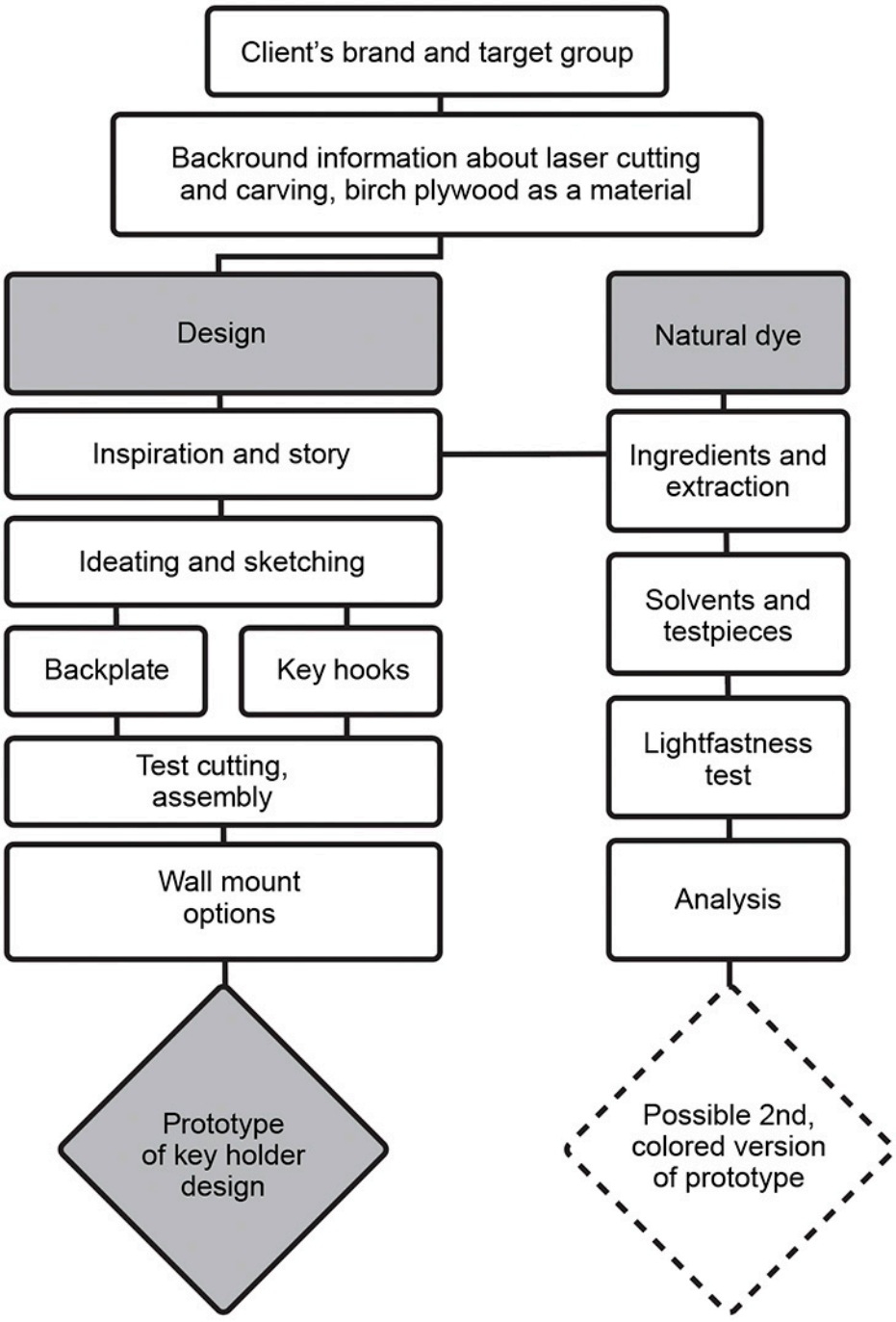
Figure 1. Frame of reference.



1.4 Project flow chart

Chart illustrates the process in simple steps, flowing from top to bottom (figure 2). Project is divided in two main parts: design and natural dye. They connect at inspiration and story which plays a pivotal role in determining the required colorants. Both parts aim is to produce a prototype of key holder design. Possibility of producing a version with natural dye application depends on the results of the lightfastness test.

Figure 2. Project flow chart.



2 Client

Papurino Oy is a small Finnish design house of three entrepreneurs located in Turenki, Finland. It was found in 2013. The leading idea is to design and manufacture wall decor products from natural materials using modern techniques. Most of the products are made of plywood with laser cutting technology. Papurino Oy is most known for their large catalogue of cartography products (figure 3). Other themes stems mainly from nature and life in any form in general. Everyone at Papurino Oy participates in turn in product design, assembly, and other daily tasks. In addition to product design, professional skills highlights visual marketing and visual arts, woodcraft skills, international sales and marketing. Core values emphasize time-lasting design, ecology and ethnics of the products and production process (Papurino Oy, n.d.). Production chains are kept transparent and local business partners and suppliers are used when possible. Papurino Oy aspires to craft products that narrate the rich tapestry of northern roots and culture.

Figure 3. Examples of Papurino Oy's product catalogue.

2.1 Target group and personas

Papurino Oy describes their target group as a people who share similar values. They prioritize ecological and ethnical production, including material choices and products that are made in Finland with transparent production chain. Nature is seen as energizing and source for inspiration. Simplistic, Scandinavian design aesthetic is found appealing (personal communication, October 8, 2023). The designer has created three different personas that can be seen in the target group (figure 4, p. 7).

Wanderer

They have a notable wanderlust for nature, urban destinations and sights, both domestic and abroad. Finnish National Parks rank among the preferred domestic destinations. Cartography holds special space in their hearts because it reveals the world in a visual way. They like to map out where they have been and what to explore next. Some of the most meaningful experiences are associated with places that the Wanderer cherishes, wanting to capture and display them on their wall as a reminder of the memories. It might be a hometown, nature/city destination or some other significant geographical locale.

Scandinavian modernist

A clean, simplistic yet personal interior style can be found in Scandinavian modernist's home. Their appreciation for niche and specific subjects is reflected in carefully chosen decorative pieces. It is a deliberate effort of assimilating their personality into the decor. Despite their individual touch, artistic style still remains Scandinavian ensuring the flow and harmony throughout the space. Color palette is usually light with the accents of muted colors.

Seasonal shopper

A person who likes to purchase something small occasionally whether to brighten their own day or to surprise a friend during visits. This individual may be looking for a perfect housewarming gifts, a thoughtful cards or a charming pot coasters as a token of affection. They appreciate seasonal ornaments and celebratory items, making them particularly keen on finding delightful pieces for occasions such as birthdays and weddings.

Figure 4. Chart of personas.

Personas

Cameron
38 years

Budget:
moderate to
generous

Key words:
"Here we go!"

Wanderer – Joy in Exploration

Explorer at heart, the wanderer has always a few new travel destinations in mind. They want to experience everything firsthand, not through someone else's eyes. Traveling is done with ecological mindfullness including carbon neutral compensation. They are interested in geography and historical aspects of the destinations.

Wanderer loves design elements that echo the authenticity of the places they explore, connecting them to the world in a sustainable and meaningful way.

They dream of doing several year-long journeys, visiting every major urban and nature destination around the world.

Riley
28 years

Budget:
moderate to
adequate

Key word:
"Hygge"

Scandinavian Modernist – Joy in Harmony

They are harmony-seeking individuals who appreciate craftmanship and ethnical values. They are interested in simplicity and slow-living as a concept. Earthy color tones and pastels are found appealing, while black is preferred as warm dark graphite, and white as light cream.

Scandinavian modernist wants to reflect their personality and activities thought the decor. It always boosts positive thinking and coziness.

They dream of having various spaces where they can immerse themselves in different moods, whether it is to calm down or energize.

Taylor
26 years

Budget:
limited to
moderate

Key words:
"Look what
I found!"

Seasonal Shopper – Joy in Finding

Joyful seeker, the seasonal shopper delights in finding unique, eco-friendly items that bring seasonal cheer. Their own excitement of finding the perfect gift is as important as the receiver's reaction.

Seasonal shopper loves to dress up and decorate their home according to current hot topics or festivities. Decorations often serve as conversational starters.

They dream of infusing sparks of joy into the lives of their loved ones with thoughtful and sustainable gifts.

3 Background information

Laser processing is a method that uses laser light to alter materials by directing a laser beam onto them. Laser cutting is a technique commonly employed for marking, cutting, and welding. It relies on laser technology and a cutting gas, typically compressed air when working with plywood. Air is used to remove smoke residue from the process, maintain the cleanliness of the laser's focusing lens and contribute to the cutting process (Kilt, n.d.).

Laser is powerful tool to use with plywood since it can cut through and also engrave the surface. This gives an opportunity for adding more details to the product. When engraving laser ablates and removes the surface material according the measures adjusted by control program (Thorpe, 2021).

Engraving, also called carving gives an option to make personable details and larger areas which can be used as a benefit for achieving certain look or brand style. It is an easy option to add logo or brand symbol to the product.

3.1 Laser cutting and carving

Cutting is done precisely by laser according to the lines input in vector graphic drawing. Carving can be done with vector or pixel graphics. It can be done multiple times at same area and also with the same picture to achieve different results. During the studies picture of a face was used in test runs. It got more impactful gaze when eyes were carved twice while other part of picture only once. Carving same area multiple times or with different settings gives also an opportunity to have more depth in texture (figure 5). However, carving should only be done on top layer of plywood. If carving extends into the adhesive layer, result looks unappealing to the eye.

Figure 5. Example of carving three times with the same power on the same area.

During the process of laser cut project studies at school it was found that carving takes a lot more time than cutting. Furthermore it is apparent that laser carves horizontal lines faster than vertical. Processed works should be placed in the cutter this in mind. It is mainly in effect when multiple works are made at one run. Because current project is about commercial product both discoveries will be taken into consideration. The faster product is manufactured the less energy consumption there is, lens lifetime and overall productivity is increased which leads to more efficient work flow. When only cutting is done, there is no significant speed difference whether cut line is horizontal or vertical.

3.2 Birch plywood as a material

Birch plywood was chosen as a material because of it's availability from a domestic provider. This helps to keep emissions caused by logistics at minimum. It is ideal for natural dye testing because of the lightness which is needed for lighter hues and strong light-dark contrast.

Figure 6. Photo of plywood surface with unique natural surface pattern.

Plywood has consistent quality which makes it great material for laser cutting and carving. Results will be easily repeatable if it has been stored accordingly in a non-humid environment (Kujanpää et al. 2005, p. 275). While quality is consistent, every plywood has distinctive, natural surface pattern that enhances each products uniqueness (figure 6). The application of dye typically makes patterns more visible offering an advance for design purposes.

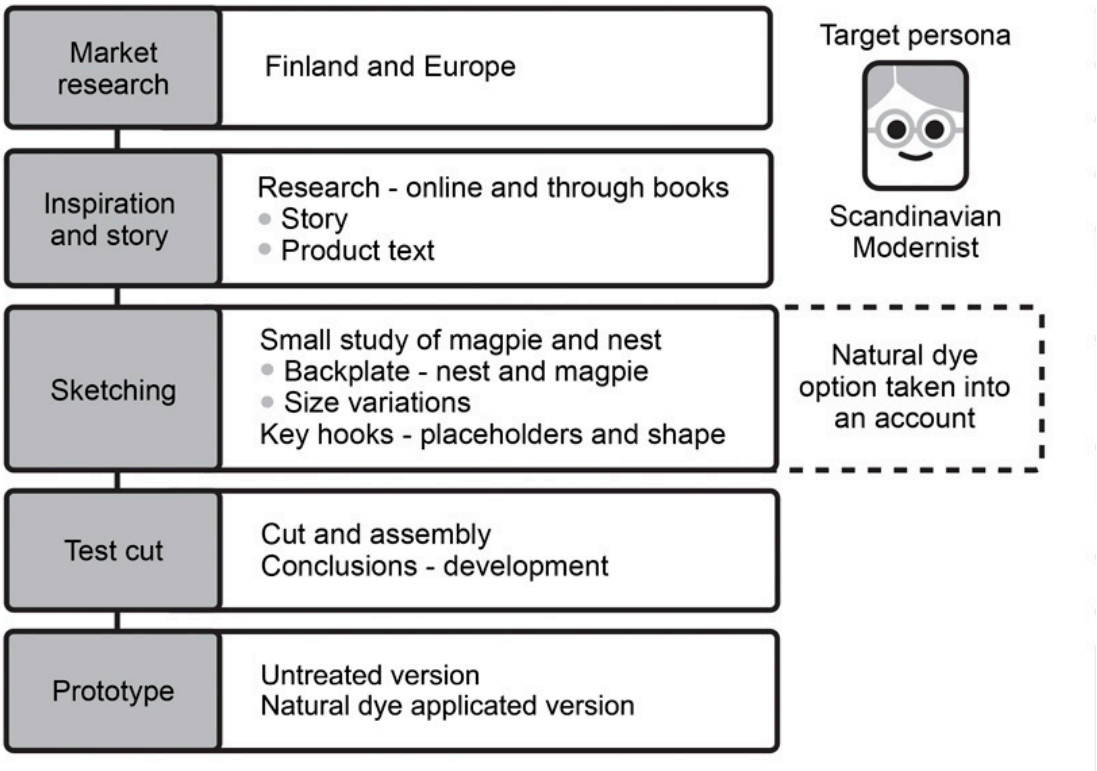
For this project plywood is purchased from Koskisen Oy. They are a Finnish manufacturer that have transparent supply chain and strong ecological values which are made visible in their annual report 2022 (Koskisen Oy, n.d.). Report is available for anyone to download from

their website. They state at their plywood is manufactured from a genuine natural material which is high-quality and renewably grown in sustainably managed forests. Chosen plywood is KoskiPly Economy which is homogenous and easy to coat (Koskisen Oy, n.d.).

4 Design

Design process starts with market research (figure 7). It will give an understanding what kind of key holder products made of plywood are available at the moment. It helps to identify what kind of themes or styles might be oversaturated in the market. Research does not include price points of the products. Ideating starts with collecting base information and stories of thieving magpie from different sources. They will act as an inspirational source for the design and storytelling of the product. Key holder's target persona from Papurino Oy's target group is "Scandinavian modernist" (figure 4, p. 7). Design process will have several different phases: small study of magpie, nest and hook design, technical aspects, test cuts and final design. In the end, the design process will culminate in the creation of a cohesive key holder inspired by the belief of the thieving magpie, ensuring a unified look and feel. Throughout the process natural dye application version is kept in mind.

Figure 7. Chart of design process



4.1 Market research

Market research involved the search of information on existing key holder products. It was done for the most part online using terms ”plywood key holder”, ”wooden key holder”, ”wooden rack” and ”laser carved key holder”. Search was done in English and in Finnish. It encompassed Europe, special attention was paid to Finland. Research included approximately 30 items.

Most of the results showed that hooks or hanging mechanisms are usually metallic or done with magnets. Some used cut key slots. Typically there was two or five hooks. Key or small holders that were designed for children had usually a cute animal or car motif. Ornamental shapes and figures were typically silhouettes, with black application or they were untreated. Laser carving on plywood was used if there was a separate product sold with the key holder, for example name tag of a key chain. Key holders themself did not have carvings. Every product with a designer label had a thoughtful and extremely minimalist design. They were generally made of solid wood, not plywood. Visually they lacked personality and did not seem to tell any story. Their design can be seen as industrial where form and function are optimized.

4.2 Inspiration and story

Research for inspiration was conducted online and through physical books. During the research it was found out that recorded concept of thieving magpie has been around very long time and is still alive and well (figure 8). It has been used quite creatively in different media with the focus on magpie’s obsession of stealing shiny and valuable things, or at least trying to steal. Loot consist usually of jewels and shiny, metallic objects. On occasions there were also keys depicted, for example in short animation called Robin, robin. Ten instances are highlighted from the research material, resonating the most with the designer's inspiration. They have been used to craft a compelling story for the product.

Inspirational discoveries

One of the most well known opera compositions tells a story about thieving magpie. Murtomäki (2021) summarizes plot in a nutshell as follows, Italian Gioachino Rossini’s well know opera composition The Thieving Magpie (1817) tells a story of wrongly accused servant girl who got death sentence for stealing silverware. At the last minute real thief was found, it was a magpie.

Within the literature there were several inspiring discoveries. Slovenian poet Krista Bendova has written a children’s book that had a poem about thieving magpie. In the poem magpie

thinks it has found a golden object but is fooled by reflection of the sun. It was translated into Finnish by Eeva-Liisa Manner in 1978 (Manner, 1978). Finnish book of poems for children called Suomen lasten runotar has a poem called ”The Magpie Composes Poetry” which depicts magpies fondness of shiny things (Helakisa, 2000, p. 236). Book about Finnish mythical birds (Ojanen, Ulv, 2015, p. 98) has an illustration of magpie in its nest with stolen shiny artifacts. Text itself does not include lore behind the picture but it can be seen recognized through the picture. Belgian comic book writer Hergé was inspired by a story of thieving magpie and included it in his The Castafiore Emerald comic book (Hergé, 1999, p. 60). It was originally published in 1963 and translated in the 90s into Finnish. In the book someone steals opera singer Castafiore’s most valuable jewel, an emerald. It is found out later that the thief is a magpie.

In the gaming world, there were two instances that were interesting. Magic the Gathering, a popular collectible card game added a card named Thieving Magpie in it’s seventeenth edition: Urza´s Destiny which was released in 1999. It had a game mechanic that states: Whenever Thieving Magpie deals damage to an opponent, draw a card (MTG, n.d.). Thieving magpies are used in several video games. They usually have similar aspects of thieving and fondness of shiny things. In Runescape you can summon a magpie familiar which boost ones thieving level and provides random chance to forage for jewelry (Runescape fandom, n.d.).

Discoveries were also made within tv-programs. In the late 1980s, the popular children’s tv-series Alfred J. Kwak was released (Siepermann). It had a character named Pikkie. He was a magpie who had a compulsion to steal and collect anything shiny. Tv-show Batwoman (2019) had a villain named Magpie. Her origin story is described as ”a museum curator who goes mad from being surrounded by beautiful things that she can never have. This leads ultimately to turning into a jewel thief that is also drawn to shiny things” (Drum, 2019). On one occasion she tries to steal Fabergé egg that misfires when Batwoman comes to interrupt it. Robin, robin is a animation available to stream on Netflix. It was released in 2021 as a Christmas short special produced by Aardman (Aardman, 2021). One of the characters is a magpie who has stolen lots of shiny things, including keys and jewelry from nearby house.

Figure 8. Chart of selected media using thieving magpie theme in 7 decades.

Decade	Medium	Title
-1960	Opera	Rossini, Thieving magpie
1970	Book	Perhonen, hassu varpunen
1980	Tv-series	Alfred J. Kwak
1990	Comic	Tintin
	Card Game	Magic the Gathering
2000	Video Game	Runescape
	Book	Runotar
2010	Book	Mythical Birds of Finland
	Tv-series	Batwoman
2020	Animation	Robin, robin

Chart shows (figure 8) that thieving magpie lore has appeared in various media throughout decades affecting people with all sort of interests. Chart starts from the 1960s and the last pick is from the 2020s. Exemplary instances of the lore has been selected deliberately from various decades to show that they have been influencing several generations of people. It can be assumed that the lore will also influence at least couple of generations in the future.

Behind every successful product, there is often a compelling story that evokes viewers emotions and conveys a message (Lewrick & al. 2018 p.171). Crafting a story for the key holder will include lore of the thieving magpie but also it's generational impact and emotional connection between it's users. Whole story is thought to be published in a print or e-mail post linked to the product. A short product description will be written based on the crafted story.

The Story

A key holder - such a simple object, yet this one possessed a strong, almost magical presence. It was the visual theme that resonated through four generations of Lockwood family. Key holder looked like a nest of magpie where it sat surrounded by shiny keys.

When dad was setting the key holder in the hallway fond memories filled his mind. He recalled how his dad used to read him poems when he was a child. One, in particular, was about magpie whose interest in shiny object led to a funny end. Later that same theme came up in a comic book that he loved so much. Keys whereabouts might have been a little bit of a problem with grandpa because his memory wasn't as sharp as it used to be. As an opera

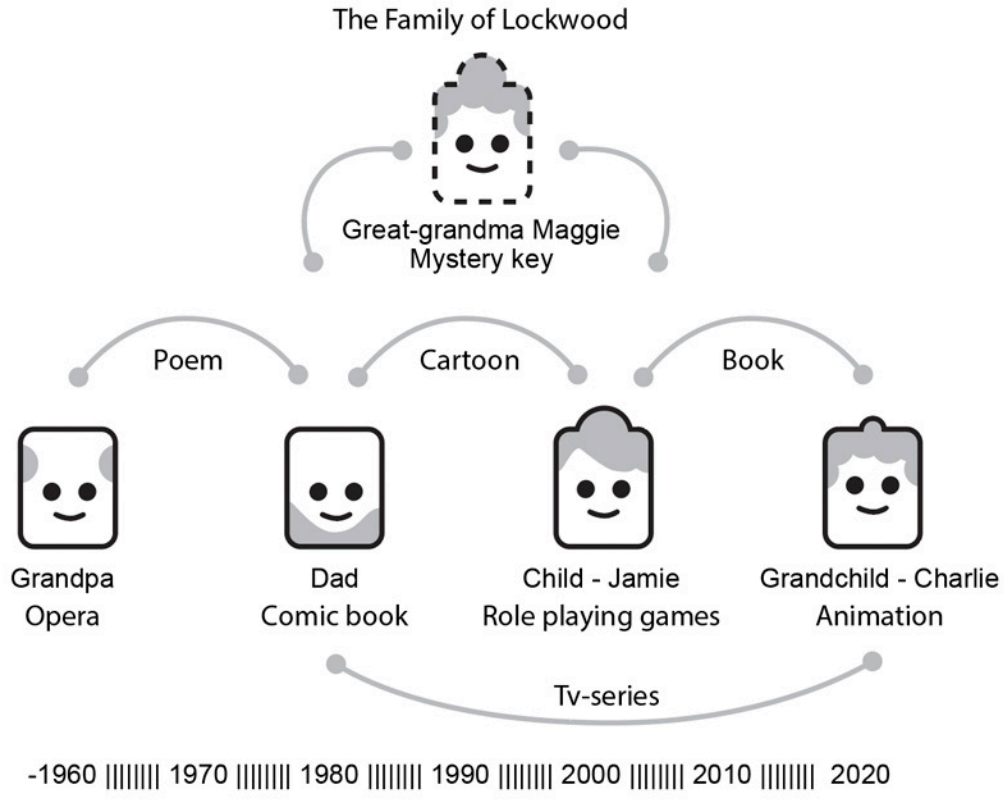
enthusiast he had a powerful experience at his first live opera: the Thieving Magpie. It was so profound he remembered it well after sixty years. Because of that he always remembers where the keys are and where to put them.

Jamie was a middle child, who from a young age liked to watch cartoons with dad and his siblings. In their teens they all got very excited and interested in playing role playing games. One of Jamie's favorite card in the table top game was named ”Thieving Magpie” which had lead to victory on several occasions. Jamie's daughter Charlie's favorite time is when she can sit with her grandpa and watch a bit scary tv-adaptation of comic book called ”Batwoman”. On her own she loves to watch animations with wool socks on and a warm chocolate milk at hand. She has started reading books with the help of her mother.

On the key holder there is one special key that is never removed. It had belonged to beloved great-grandma Maggie. No one knew what it could unlock. Every Christmas, the whole family loved to speculate about it. Wildest thoughts included a chest with valuable stolen treasure.

Chart shows the connections between family members and discoveries (figure 9).

Figure 9. Chart of connections within the story.



Product description

The Magpie’s Nest Key Holder is a timeless functional item that connects generations of people with enchanting tale of the thieving magpie. Hang your shiny keys on the hooks, merging everyday utility with the spark of magic. Cherish the captivating story behind it every time you use it.

4.3 Sketching

Sketching process was separated in two main phases. First one included ideating the back plate which is the magpie’s nest and bird itself, the second one is the key hooks. From the beginning it was taken in to account that back plate design needs to have areas for the hooks. Visual design should appeal to different ages and generations within the target group and persona. Figure of the magpie plays a key role achieving it. It should look friendly and approachable, perhaps a bit naive so it matches traditional folklore aesthetic. Additionally, the style have to fit into the client’s visual aesthetic.

Magpies build their nest of small twigs into a shape that resembles a sphere. It has roof unlike many other bird species´ nests (figure 10).

Figure 10. Photo of magpie’s nest (Railio, 2019)

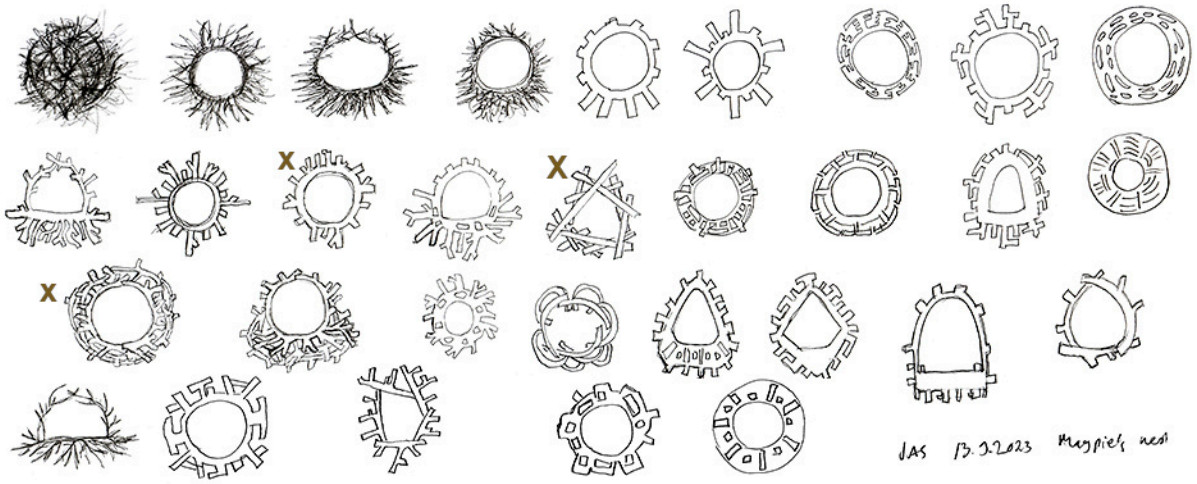
4.3.1 Back plate

Sketching started by drawing couple variations of magpie in different positions (figure 11). It was a small study to find all color areas characteristic for a magpie. Prototype will undergo only one laser carving run for the color areas; thus, only one color is allowed to be used in the figure.

Figure 11. Small hand drawn study of magpie's color areas.

Sketching of the nest started with a rough drawing of the actual shape of the nest, a sphere. From there on sketching progressed to more of a graphic shape. A lot of ideas and variations were drawn and then presented to the client from which they picked their favorites. It was explained that magpie figure is going to be in the middle of the nest and added to the next sketches. Shapes and ideas were open for a discussion for the direction to further the design. Some of the sketches felt too far from nest like appearance. Symmetry was brought into discussion as a preferred shape, but it could be broken partly if it would make outlook more interesting. There were three favorites (figure 12), one was the most liked because of it's very simplistic yet clearly nest like appearance and it fit very well into client's brand.

Figure 12. Drawn back plate sketches. Chosen ones marked with x.



Next phase was to continue developing design with digital sketches and to include figure of magpie in them. Three digital sketches were created (figure 13) on the base of conversation and previously chosen sketches. All new sketches are very simplistic with different feel to them. Sketches include five key hook placements which can be seen as small square holes in the designs (5 x 5 mm in actual size). Placements are set in a way that hanging keys will not obstruct the view of seeing the head of the magpie.

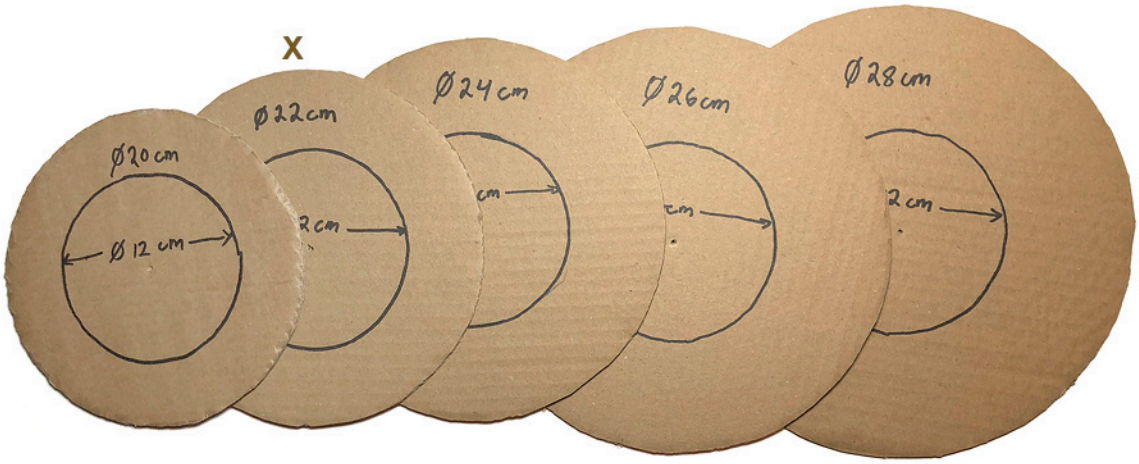
Figure 13. Three digital sketches with magpie included.

All versions brought up different associations within the client and designer. First one was thought of having the most nest like appearance. Lines reminded of twigs and little branches. Second one looked a bit too industrial and reminded of crate. Third one looked nice but had a bit too snowflake-like feel to it. First one was chosen to be further developed.

Size examples

To help to visualize possible sizes various examples from cardboard were created (figure 14). Sizes varied in outside diameter (20, 22, 24, 26 and 28 cm) while the placement space for magpie remained the same (ø 12 cm). Material was cut from used packaging boxes and it was recycled afterwards. When choosing the size with the client, there were discussions about where the customers would likely mount the key holder. The idea of placing it in a small hallway, where the space is limited, was brought up. It was taken into a account that the size could not be too small as it might diminish the visuality of the product. With these considerations in mind second smallest option was chosen, with the diameter of 22 cm. It was thought to be a good starting point and later possibly adjusted depending of the functionality and the look when key hooks are attached.

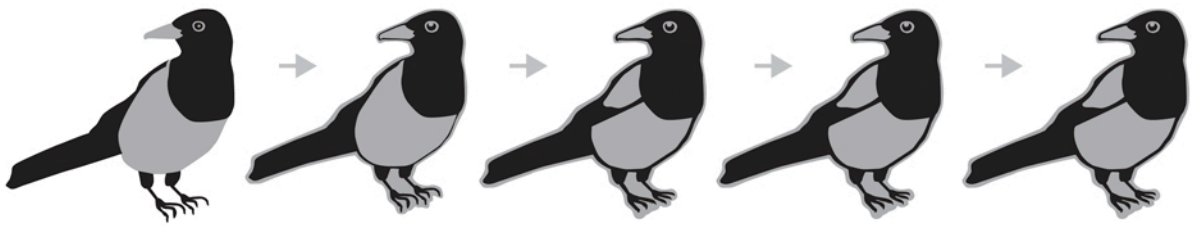
Figure 14. Cardboard models of back plate for visualizing various sizes.



Magpie figure

Figure in the first sketch (figure 15) was thought to be good starting point. It did not need major changes, just a minor adjustments to strengthen the visual appeal. At this point possibility of applying natural dye application by hand was considered which lead to simplifying the eye a bit. Magpie got a small rim all around the edges and separate light area in it's wing. While they make the overall look more interesting, they also serve a practical function: safeguarding carved areas during the sanding off the burn residues. Some minor simplifications were made in the beak and the feet.

Figure 15. Development of digital sketching of magpie.

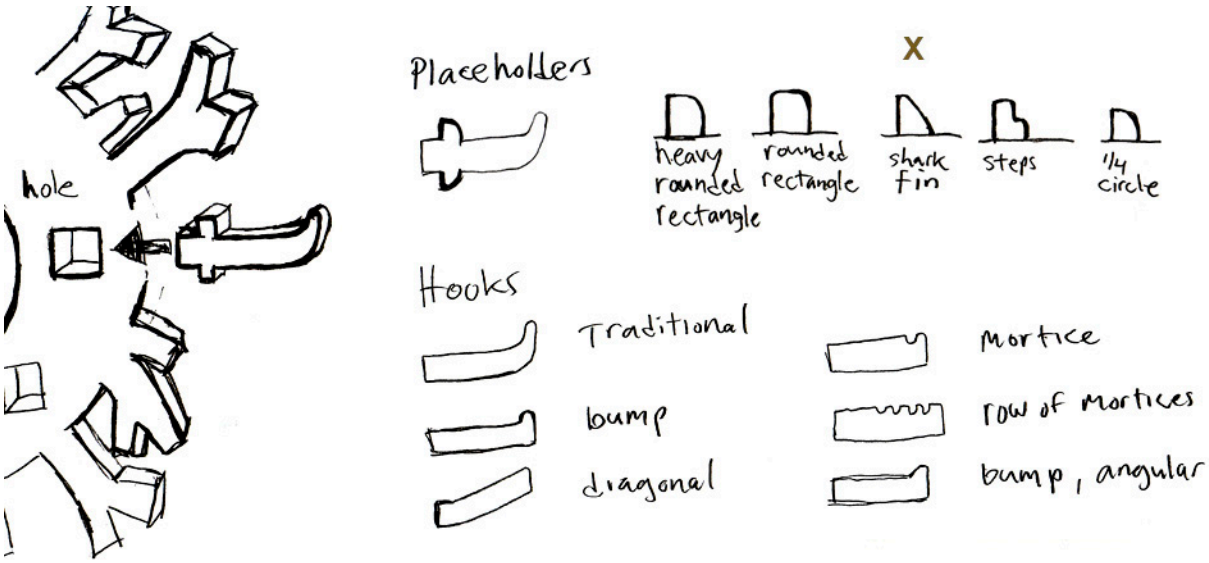


4.3.2 Key hooks

Design started from the idea of having key hooks resembling small twigs that stick out of the nest. Plywood thickness used in the back plate and hooks is 5 mm. For the attachment 5 x 5 mm holes will be cut in the back plate to form symmetrical shape. Hooks will be attached vertically into the back plate ensuring their durability.

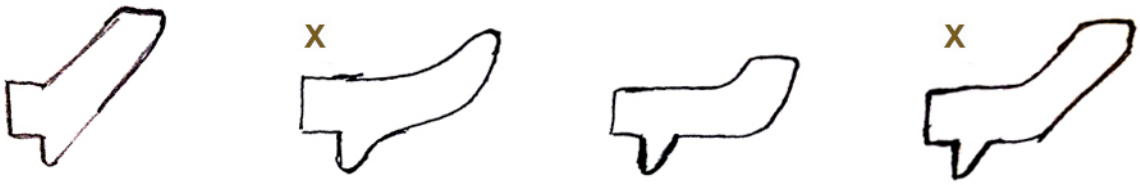
Key hooks need placeholders to lock them tight into the back plate. Five different shapes were sketched, Each of them could be used to emphasize the feel of the design or just to be an interesting little detail. First ideas were quick sketches without too much thinking. They served as a base for discussion with the client. A shape described as ”shark fin” was chosen (figure 16). It was thought to be most organic yet simplistic and look almost like a base of the branch.

Figure 16. Ideating placeholders and hooks.



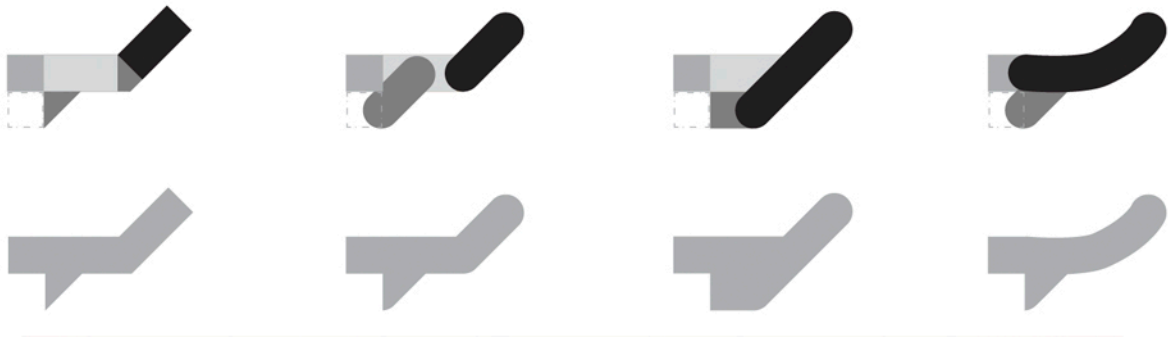
After discussion with the client, it was determined that there is no need for upper placeholder. Only one placeholder underneath is required. It will make a strong enough support for the weight pressure exerted by the keychain from above. The angle of the hook should be large enough to securely hold the keys in place. There should also be some space between the plate and the hook’s angle. This was thought to prevent the keychain from banging against the backplate when it is hung in the hook. Two of the sketches were selected for further development (figure 17).

Figure 17. Sketching of different hooks with chosen placeholder.



Three shapes were created digitally for the test cut (figure 18). They all have clean and geometrical shape that follows the shape of the back plate. First the base shape was created and then altered to form three different versions. Different shades of black show the elements that were used to form shape for test cut.

Figure 18. Digital sketching of key hooks.



4.4 Test cuts and assembly

Test cuts were done at client's workshop. They were planned to be done in couple runs to minimize energy and material consumption. First run included backplate (figure 19) and three hook shapes (figure 20). Second test run included developed hook shapes and different hole sizes (figure 21). It produced a perfect option to be used (figure 22).

Figure 19. Picture of back plate test cut file.

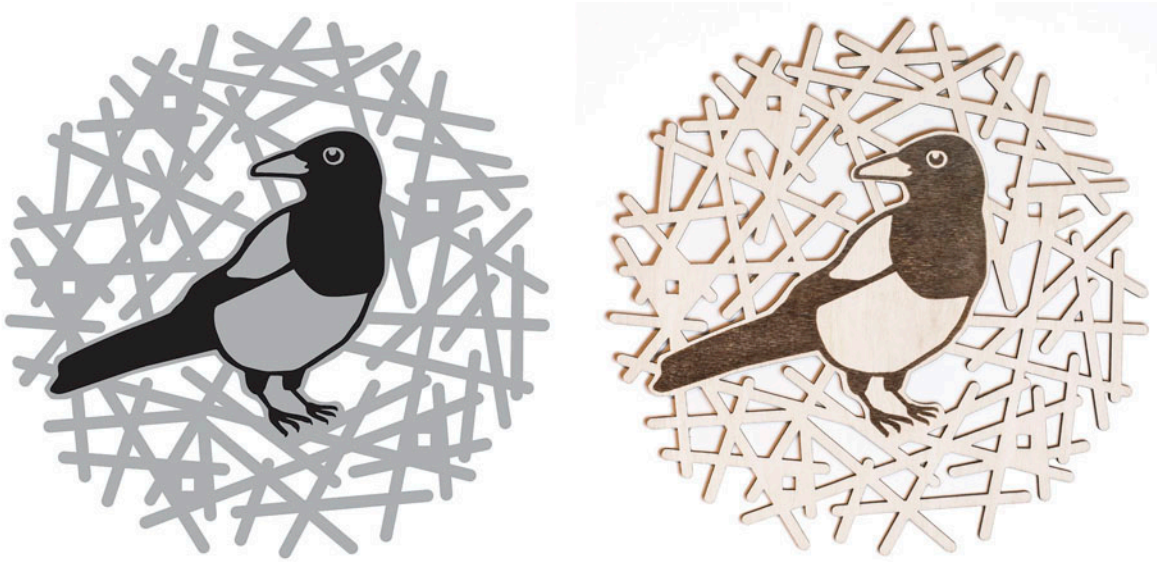
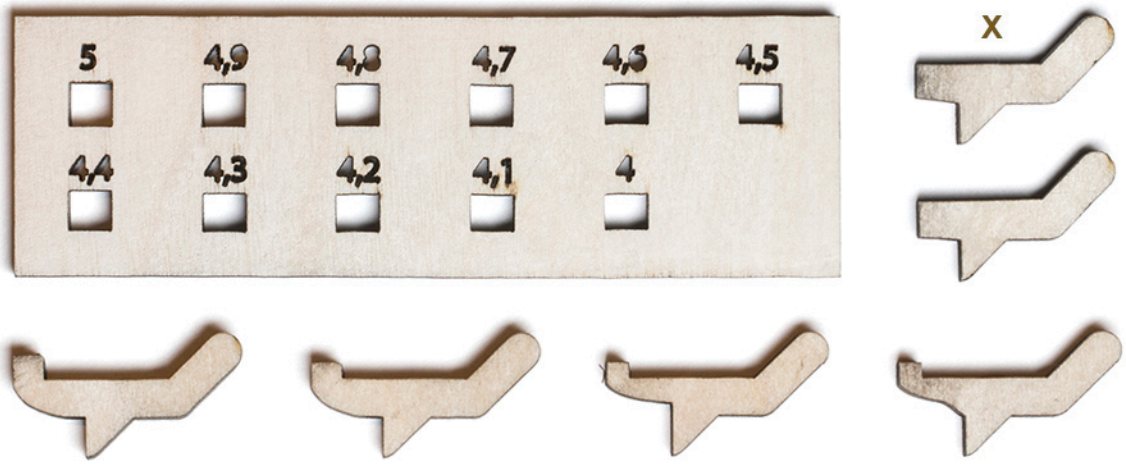


Figure 20. Picture of hooks test cut.

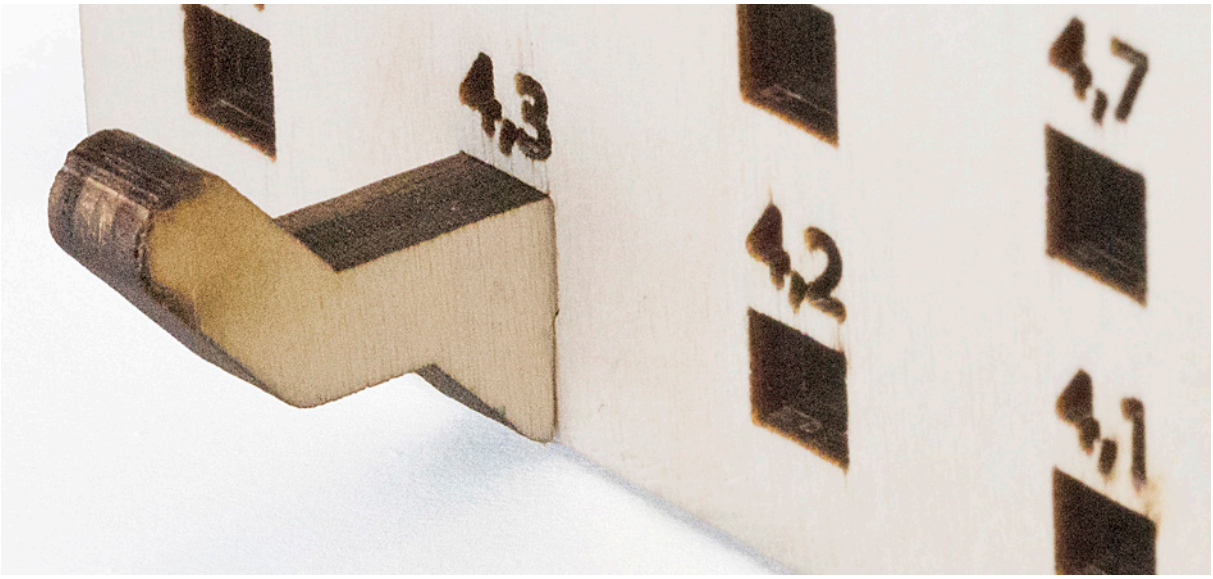
Backplate's visual outlook was achieved. Chosen hook shape is marked with X. It was thought be most in line with the visual appearance of the backplate. Holes for the hooks needed adjustment because they did not produce tight enough lock. It is noted that even though laser cut is precise it is slightly larger than file's measurements. In conclusion a test plate with different hole sizes and several hook shapes were designed (figure 21).

Figure 21. Picture of test plate and new hook shapes



Test plate had eleven different hole sizes. They started from 5 mm and went smaller in tenth of a millimeter all the way to 4 mm. Two different lock mechanisms were designed for hooks. First one was a wedge-shape form. Second had a placeholder that is slid through the hole. It locks the hook from behind in place with the help of front placeholder. Perfect fit and strong lock was achieved with wedge-shape form and size 4,3 mm hole (figure 22).

Figure 22. Picture of perfect fit of hook and hole.

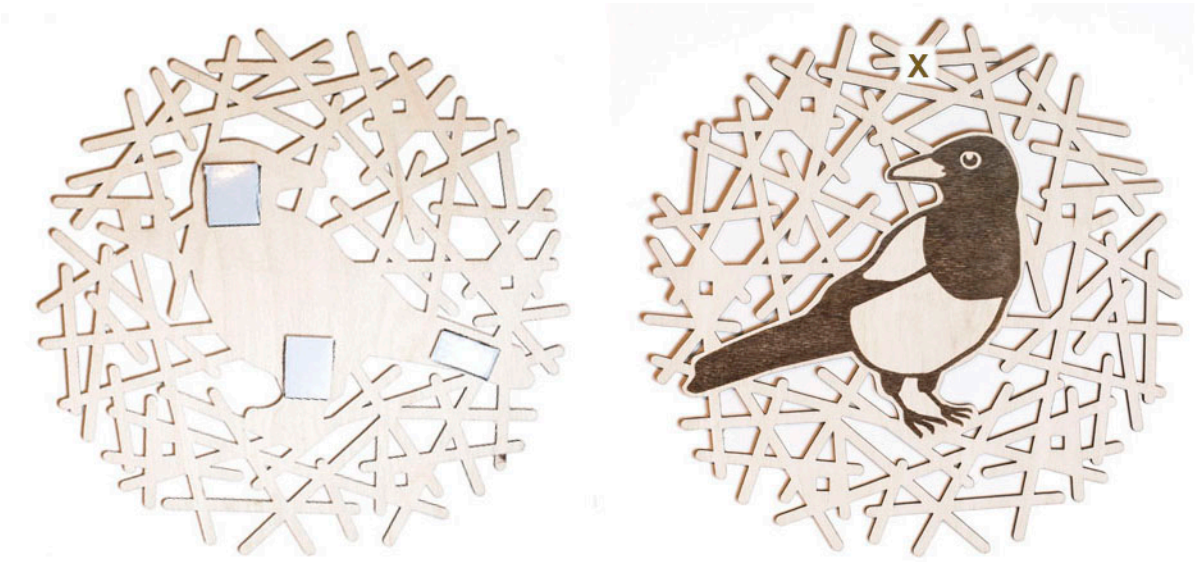


Despite the strength of the lock, it was decided that a droplet of glue will be used in end product to further enhance the firmness of the the attachment.

4.5 Wall mount

The client recommended that the 3M Dual lock SJ3540 fastener be used for mounting. They have been using it before with great success. It is designed to be used on powder coatings, plastics and other low surface energy materials (3M, n.d.). Key holder will have three pieces of fastener to ensure strong hold. They will be positioned in the middle behind the magpie figure on the key holder. If fastener is not suitable for tight lock because of the wall material, there is a place for screw (figure 23). It is thought to be used only if necessary since it will be visible.

Figure 23. Placement of fasteners and placement of possible screw, marked with X.



4.6 Final prototype

The Final prototype measures 22 cm in diameter. It exhibits a strong light-dark contrast, achieved by using untreated natural color of Finnish birch and carving specific areas to create darker sections. The magpie looks directly at the viewer while its head is turned to the left. This gives a certain stillness to the appearance. Hooks encircle the magpie, ensuring that keys hanging from them will not obstruct the bird's head (figure 24).

Figure 24. Photo of final prototype.

Figure 25. Photo of final prototype in isometric view.

Figure 26. Close up photo of the prototype.

Figure 27. Photo of final prototype with keys hanging on the wall.

5 Natural dye

In this portion of the thesis focus will be on the possibility of using natural colorants for application in substitute for synthetic ones when used on birch plywood. Aim of the test is to get earthy, subtle and soft colors. To verify the results they will undergo a lightfastness test.

Sustainability aspect can be taken into an account in several phases when utilizing natural dye process in product design; 1) What is the color source and how it has been cultivated, collected, chipped and will it be used as fresh or dried. 2) Extraction process, liquid or powder form, mixture or pure compound. 3) How it is applied to product. 4) Designing process and the end product. (Räisänen, 2022). In this thesis only parts 3 and 4 are taken into account because colorant powders are processed prior to the thesis by Hamk Tech and given to the designer.

5.1 Chosen ingredients

Three colorizing ingredients will be tested. Selection have been made on the base of need with the prototype's coloring. Ingredients are biochar, indigo and spruce (figure 28). Extraction process have been made prior at Hamk Tech laboratories. They have provided a stain to use with test pieces. Client has provided an UV-protective spray to use after the dye.

Indigo

Woad (Isatis tinctoria) is chosen as a raw material and it is purchased from Natural Indigo Finland. It was ground to a powder in 2020 from 2019 crop. Material provider (Natural Indigo Finland, n.d.) describes woad as ”biennial yellow-flowered plant that contains same colorant as the indigo plant. However, the blue color obtained from woad is more durable than the dye obtained from the indigo plant, which makes it particularly suitable for coloring.”

Spruce

Colorizing ingredient is extracted from the bark. Spruce is second most common tree in Finland (Luontoportti, n.d.). It was chosen to be a test dye because of the color it can provide and possibility for larger scale of use. Industrial processes i.e. manufacturing paper produces side-streams of bark that could be used as a coloring agent for multitude of products. It is to be noted that collecting bark from woods neither from living nor dead tree is not included in everyman's right in Finland (Metsähallitus, n.d.).

Biochar

Chosen char is half birch and half alder. Hyötykasviyhdistys defines biochar as follows: ”biochar, i.e. soil char as solid and stable elemental carbon in which the natural pore structure of the biomass has been preserved. It is produced at a temperature of 350–800 degrees in oxygen-free pyrolysis, i.e. dry distillation.”

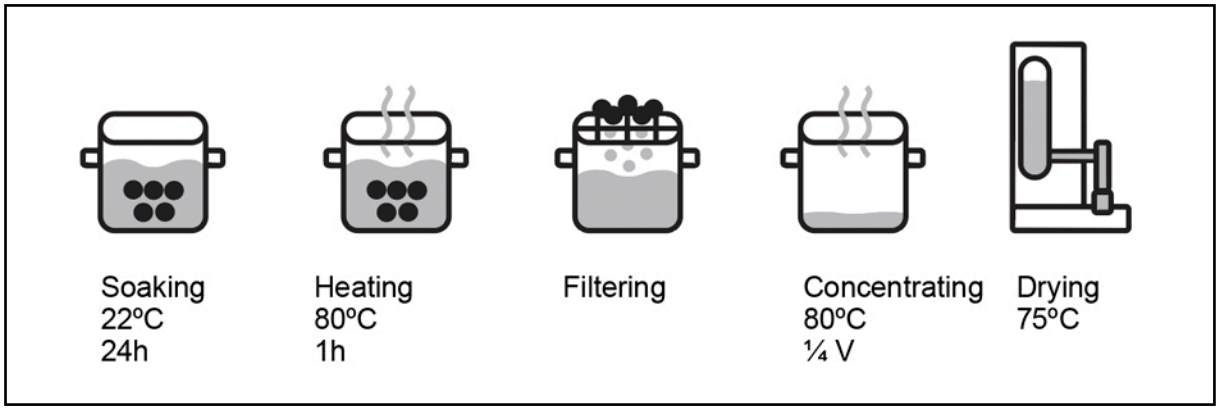
Figure 28. Picture of chosen ingredients in powder form: biochar, spruce, indigo.

5.2 Extraction

According to PhD, research professor/food development Hopia (2016) extraction process can be described as ”an isolation method in which desired substance is separated from one solution to another based on the solubility properties of the substance.” In this case desired substance that needs to be separated is dye.

Hamk Tech Project Engineer Roosa Helander describes color extraction process from spruce bark as follows, spruce bark is soaked in room temperature for 24 hours, heated up to 80 degrees and kept there for an hour. After that, the extract is suction filtered through filter paper to separate left over bark pieces. The filtered extract is concentrated to increase the dry matter content. Concentrated extract is processed further with mist dryer (Buchi Mini Spray Dryer B290) to form the powder (personal communication, September 4, 2023). Process is visualized in the picture (figure 29). Left over bark pieces can be composted.

Figure 29. Picture of extracting process.



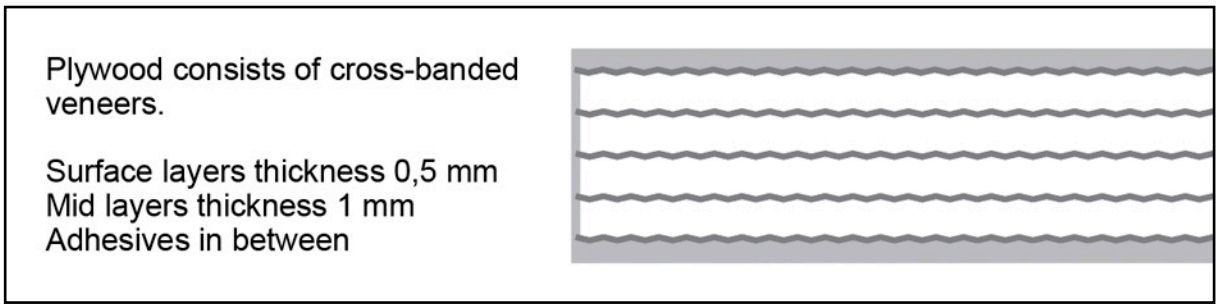
Extracted dye can be used in liquid or in powder form. However powder form has it's benefits; the amount of dye can be calculated exactly which helps to achieve reliably and repeatable dyeing results. It is also easy to store and preserve (Räisänen et al. 2017, p. 224). In this test dyes are used in powder form.

5.3 Solvents

Two different solvents are tested, water and stain. Water at a temperature of 54 degrees Celsius is used in the water-based mixture. Stain is water-based Tikkurila Parketti Ässä Petsi. Proportions used in dyes are 1 g colorant to 10 g solvent (1:10). Biochar and indigo resulted in good thickness of dyeing liquid while spruce ended up quite thick. For applying the dyes simple watercolor brushes were used. One layer of dyes were applied since aim was to get subtle results and plywoods natural texture to be clearly visible. Drying time was 4 hours in room temperature before using UV-protective spray (Nanostone Ultimate line NS 90) provided by client. Spray also boosts water and dirt resistance.

Birch plywood provider Koskisen Oy spokesperson advised "not to use large amount of water with plywood since the adhesive between layers is not waterproof" (personal communication, May 4, 2022). To avoid any impact on adhesives dyeing is carefully conducted only on surface layer in this test (figure 30).

Figure 30. Picture of sectional view of 5 mm thick plywood.



5.4 Test pieces

Total of eight different test pieces were designed. Two for each of the colorants, one for stain and one for water-based mixture. Additionally, a clear stain finish and an untreated test piece were created to serve as a reference point for evaluation.

Test pieces dimensions are 30 x 100 mm. They are made to fit all together in lightfastness device at one run. Test pieces are made of 5 mm thick KoskiPly Birch Economy plywood.

There is a possibility that plywood used in the prototype might be different thickness but since the tests are made on a surface level, thickness of the plywood does not affect the colorizing results. Test pieces were produced at client's work shop and lightly sanded to remove burn residues before applying the dyes.

In the simulation half of the test pieces are covered to block light and other half is exposed to it. Top and bottom half are mirroring same kind of test areas. Each of the test pieces have a text to describe what colorants and mixture have been applied. There are engraved symbols that are drawn with 3 point line. Lines have two purposes, one is to have a clear visual reference what colorant is used and the other is to see how colorant works on thin engraved line. There are also larger engraved test areas on top and bottom parts, sizes 8 x 30 mm.

Words used in test pieces (figures 31, 32, 35) kuusi=spruce, biohiili=biochar, petsi=stain, vesi=water, puhdas=no finish.

Figure 31. Picture of test pieces before applying the dye.

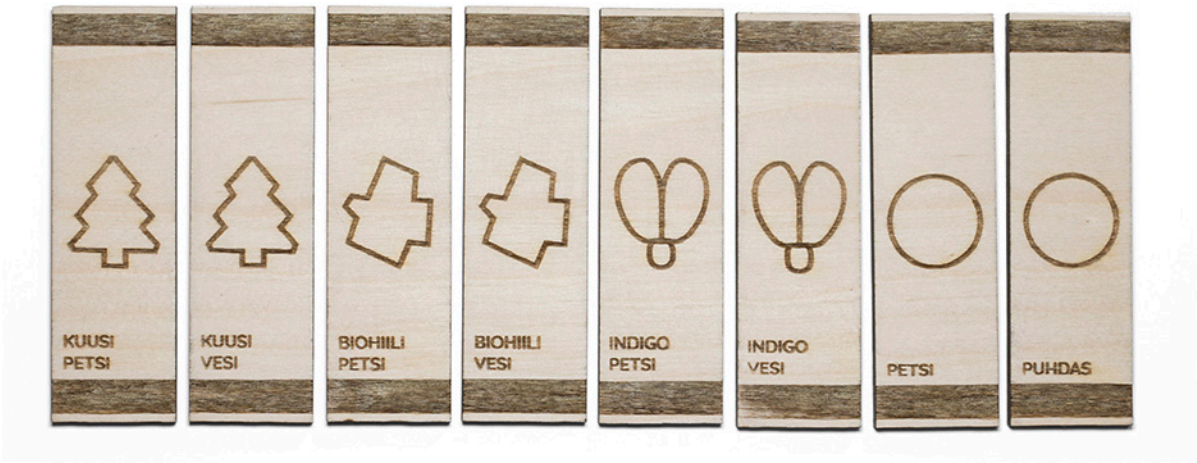
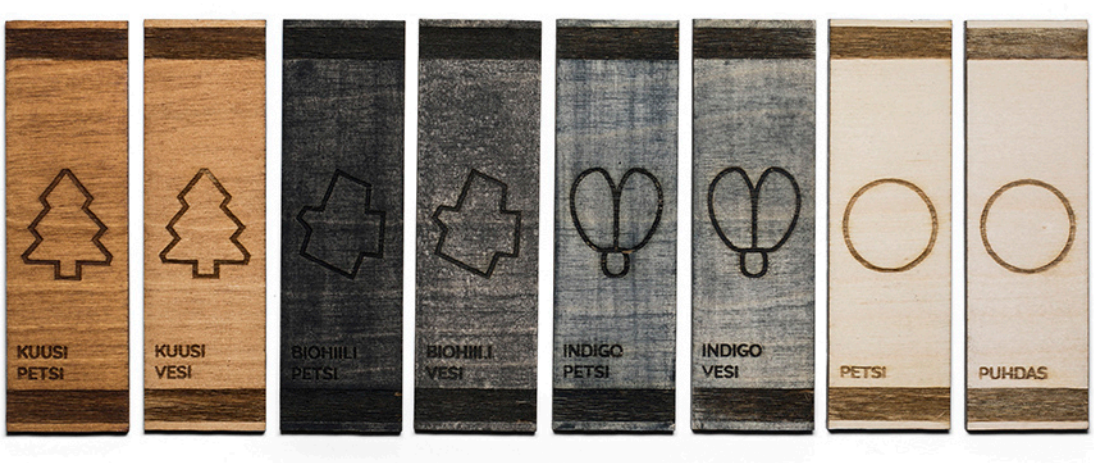


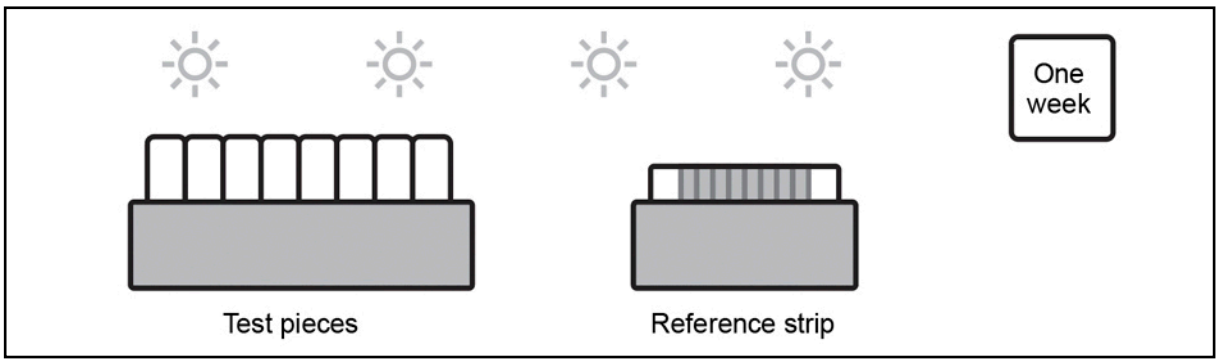
Figure 32. Picture of test pieces with natural dye applied and left to dry for 4 hours.



5.5 Lightfastness test

Lightfastness test is done in a simulation that shows how much colors will fade when exposed to light for a certain amount of time (figure 33). Device simulates sunlight shining through a window. It gives an estimate of lightfastness rather than absolute time. Test was done in Heraeus Industrie Technik Suntest CPS + -device. All the test pieces were lined up in a tight row with a metallic plate covering half of the surface. Other half is left uncovered to be exposed to light. Also a small standardized blue wool reference strip was included to help to evaluate the color fade. Device was set to run for a week.

Figure 33. Picture of lightfastness test simulation.



Reference strip

Strip consist of eight dyed wool bands which fade at characteristic rates (figure 34). It is called Blue Wool System which is also known as the International Standards Organization R105 series (ISO). Each band is colored with a blue dye that fades after exposure to a certain amount of light. Each of the reference band takes about two to three times longer to begin fading as the next lower in the scale (Materials Technology, n.d.).

ISO sensitivity system was build for the need of communication of behavior of materials and color in their response to light. It also helps to communicate concepts of fading to non-specialists, and tends to be more convincing than vague warnings (Colby, 1992).

Figure 34. Picture of reference strip.

Figure 35. Test pieces after the lightfastness test.

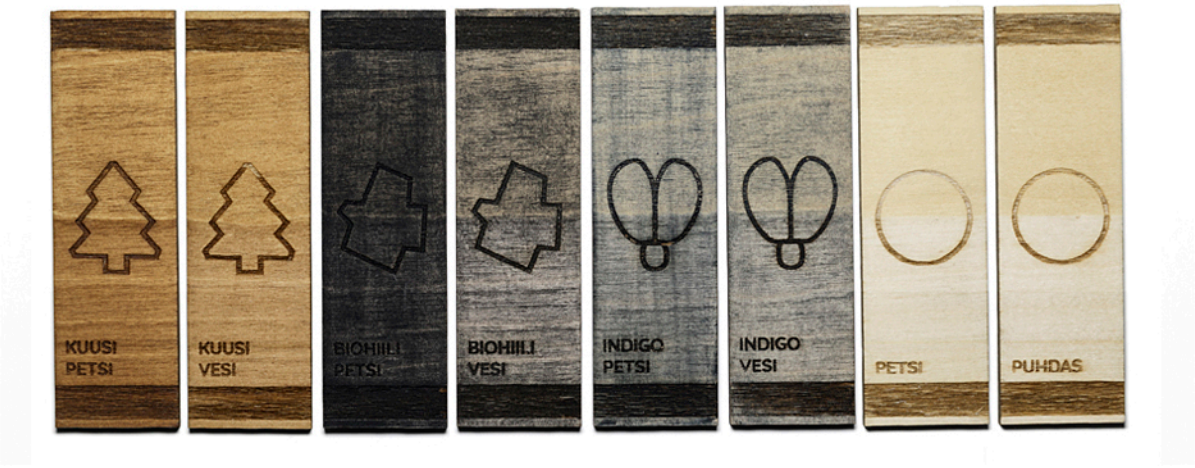


Figure 36. Chart of test results and comments.

Ingredient	Solvent	Lightfastness	Comments*
Indigo	Water	5	Fair, unchanged for 15-50 y.
	Stain	4	Fair, unchanged for 15-50 y.
Spruce (KUUSI)	Water	6	Very good, unchanged for 50-100 y.
	Stain	4	Fair, unchanged for 15-50 y.
Biochar (BIOHIILI)	Water	5	Fair, unchanged for 15-50 y.
	Stain	8	Excellent, unchanged for more than100 y.
Stain (PETSI)		4	Fair, unchanged for 15-50 y. (Change from light to dark.)
No finish (PUHDAS)		4	Fair, unchanged for 15-50 y. (Change from light to dark.)

Estimate for fade in comments* section (figure 36) are based on blue wool / astm lightfastness standards (Gottsegen, 2016). Test results were assessed visually by comparison with standardized blue wool reference strip and test pieces against a white background.

5.6 Conclusions of the natural dye

Results show that birch plywood as a material darkens and turns more yellow when exposed to light for a longer period of time. This is apparent in all test pieces. Every dye had at least fair lightfastness. This means that even if the product would be in direct sunlight indoors it is fade-resistant at least 15 years. Indigo and spruce have better lightfastness with water

solvent than with stain which is surprising because generally watercolor paints are more susceptible to deterioration from light than other paint mediums made with the same pigments (ccaha, n.d.).

It is to be noted that while biochar with water solvent has fair lightfastness it has poor adhesiveness. It is subject for wear and tear thus not suitable for functional item. With stain this problem did not exist and lightfastness was excellent. An interesting discovery was that carved areas with stain turned out lighter than ones left untreated. This suggest that non-dyed products with carved areas should remain untreated if if suitable for their function, as they maintain their light-dark contrast better without an application.

Results prove that a natural dye application for the prototype is possible to do with lightfastness at least for 15 years. Stain based solvent will be used since it provides strong colors while still being translucent and there is no adhesiveness issues with biochar.

Figure 37. Photo of final prototype with dye application and keys hanging on the wall.

6 Results and conclusions

As a result of this thesis a prototype for Papurino Oy was produced. It is made of Finnish birch plywood. It is cut and carved with a laser cutter. Visual style is Scandinavian, clean and simplistic. It fits perfectly into Papurino Oy's product catalogue especially for "Scandinavian modernist" persona (figure 4, p. 7). A colored version of the prototype was a success and can be added to the client's catalogue.

The key holder design carries a captivating story of thieving magpie. It has been influencing people through several generations and is widely known in the Western world. A new, compelling story was crafted based on that lore. It enhances the product's appeal drawing inspiration from multiple media sources, including opera, literature, video games and television series. New story features a cast around one family that are connected in a surprising way by the tale of thieving magpie. A shorter version of it was crafted to be used with product description.

The folklore of thieving magpie is visually implemented in the product, both in it's design and function as a key holder. Hung keys represent the loot magpie has stolen and brought into it's nest. Hooks of the key holder are made of plywood, the same material as the backplate. They are designed to resemble twigs, aligning with the lore.

During the lightfastness test of natural colorants, it was proven that stain-based natural dye is better suited than water-based for the use in functional item when used on birch plywood. All of the three tested colorants, indigo, spruce and biochar had a fair lightfastness which means they won't fade at least in fifteen years. They can be used for non-functional or functional items depending on the use of the object.

Both versions of the prototype can be considered successful. They provide an option for client to include either one or both in their catalogue.

The results obtained from the lightfastness test of natural dye application on birch plywood can serve as a solid foundation for future studies. This data can be further explored with a wide range of colorants and materials.

7 Reflection

The designer shares his thoughts about the thesis process. One of the choices for the chosen topic was to expand my skills towards functional items. It was accomplished. Dividing the thesis into two parts proved to be a beneficial decision. It enhanced the structure and the clarity of the thesis. In the end, they converge when colored version of the design is produced.

The process of designing a functional item for Papurino Oy was a slow but fruitful. Although the schedule needed to be revised a couple of times, there was no significant issues doing so. Dialog with the client at different phases of the design was constructive, beneficial and lead to smooth progress to the next phase.

Conducting cutting tests and actual prototype in client's workshop proved to be highly beneficial. This ensures that the final product can be produced without additional adjustments to the machinery or the digital files.

Researching the tale of thieving magpie was very engaging. It revealed how deep and wide a folklore can reach and still be thriving. It seems to continue doing so. Found data inspired me even more with creating the concept for the key holder. Writing a short story using all the information I had discovered was complicated. It was kind of a mathematical puzzle. My goal was to highlight multiple connections between people that one folklore can make. It can have impact on several generations. I believe I managed to craft a short story with a mystery ending that can resonate with a large audience.

Collaboration with Hamk Tech was efficient way to acquire researched knowledge about natural dyes. It sped my own research a lot which was necessary, which was essential given that natural dye research was only a part of my thesis. I found researching natural dyes very interesting. They offer a versatile option for enhancing the uniqueness and colorfulness of plywood products. The results of the lightfastness test provides a solid foundation for future research endeavors. I gained a valuable insights of the extraction process of colorants during my research. It is a process that can be conducted to a certain extent in any workspace. This capability enables me to continue testing natural dye with ease.

In conclusion, all the questions posed were addressed, resulting a product of which I am satisfied, even proud.

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Appendix 1. Thesis data management plan

1 Management and storage of research data

Collected photos, measurement results and observational data acquired during the thesis process are stored on the personal computer of the thesis author. Physical samples are stored by the author of the thesis. Data security has been ensured through a firewall and closed internet connection. Only the author has access to the material acquired during the thesis process. The data has been backed up on an offline hard drive, which is not connected to the internet.

2 Processing of personal data and sensitive data

No personal data has been processed during the thesis. The client has provided written consent in the commissioning agreement, allowing their name and information mentioned in the thesis to be published on the Theseus, a public thesis portal. There is no confidential information in the research material or the thesis.

3 Ownership of thesis data

The thesis and its results are entirely owned by the author. The use and ownership of the prototype will be negotiated separately with the client after the completion of the thesis project.

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