Antimicrobial Finish on Cotton Fabric with Food Wastes

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Abstract

Sustainability and upcycling are growing concerns. One way to ensure this is proper waste management and reduction. Some food wastages, to be specific lemon peel, orange peel and ginger peel are used here to develop an antimicrobial finish on knitted cotton fabric via the exhaust process. Each of these possesses inherent antimicrobial properties and was tested in the medium of two distinct microbe- *Staphylococcus aureus* and *Escherichia coli*. Though all of the extracts from the peel showed some extent of anti-microbial properties, the inhibition zone result varied depending on microbes and extracts. In addition to that, the durability of the finish and GSM of the fabrics (before and after the finish) were also tested.

Keywords— Lemon, orange, ginger, upcycling, antimicrobial properties.

1. Introduction

Initially just used to cover the body, textiles are now also employed to keep the body warm. It eventually became a form of identification and fashion. It is now employed in a variety of fields, such as sporting, protective clothing and health and hygiene. Since they are constantly in contact with the body, all of these clothing require protection from microbes. Antimicrobial finishes are necessary to keep clothing clean and fresh for a long time. Antimicrobial coatings are gaining more and more awareness. Its use has grown both in terms of volume and across many industries. Antimicrobial finishes are now used in casual clothing instead of just for health and hygiene. Commercially inorganic or synthetic antimicrobial agents are more prevalent. They include phenols, metals, salts, quaternary ammonium compounds triclosan and others [1]. In recent times, the concept of sustainability is very popular. We all want to live more sustainably. Everyone seeks out natural, eco-friendly, organic and biodegradable items in light of this. Therefore, it is in most people's favour to use natural antimicrobial agents. They are chitosan, natural colors, herbs, Aloe vera gel, tea tree oil, eucalyptus oil, tulsi leaves and medical plants, among others [2]. Researchers were inspired to investigate sustainability with antimicrobial finishes using plant extracts from components including roots, stems, leaves, fruits and flowers. Utilizing natural substances is better for the body of the consumer as well as the environment [3]. An antimicrobial finish indicates that it limits or reduces germs. In the right environments, heat, humidity and adequate food promote the growth of microbes or microorganisms. It may result in unfavorable color changes, stains, unpleasant odors and fiber degradation in textiles. Microbes damage natural fibers more than synthetic ones. The effectiveness of cells and the membrane's integrity are affected by antimicrobial agents. According to this concept, there are two categories of antimicrobial agents: biocidal (eliminates microbes) and bactericidal (inhibits the growth of microorganisms). The finish's longevity is preferred, although it can only be achieved using synthetic finishes rather than natural ones. The synthetic finish, however, may harm beneficial bacteria and pollute the environment [4].

Waste management and storage are becoming increasingly challenging to maintain. Dump sites may contain hidden jewels if wastes can be recycled or used to create something useful. Utilizing food waste to create an antimicrobial finish is the aim of this study. Lemon peel extract, orange peel extract and ginger peel extract are the ingredients used. These won't harm the cloth or have any negative effects on the body. Upcycling is the practice of reusing objects and materials that have reached the end of their useful lives or are about to be discarded in order to increase their worth. Recycling, in contrast, frequently results in at least some value loss. The practice of upcycling is also known as repurposing and mending. It is a highly discussed subject in the field of fashion and textiles. According to Fletcher (2013), upcycling initiates the textile industry to "rethink the purpose and value of fashion products" [5]. The goal of the current effort is to upcycle unused or discarded material to something value-added. The incorrect use of food resources must also be taken into consideration together with the serious issue of textile waste. As the waste output is increasing today, its storage requirements are becoming more urgent [6]. A large portion of waste comes from people's daily consumption of food. Among those wastages, some are naturally antimicrobial. Lemon peels or *Citrus Limon* contains a high amount of fiber and vitamin C. It also has a small amount of calcium, potassium and magnesium.

Family : Rutaceae.
Genus : *Citrus.*
Species : *C.limon.*

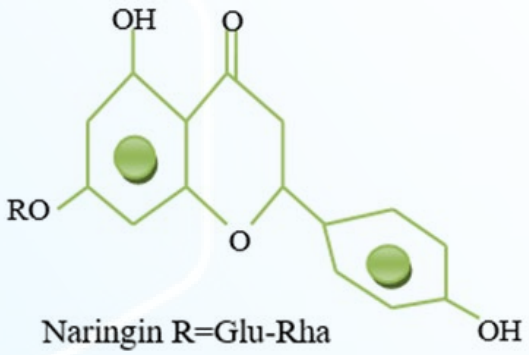

Figure 1.1: Chemical construction of lemon peel extract

Lemon peel has γ-terpinene, terpinolene, d-limonene and citral in it. It also has relatively higher beta-pinene and γ-terpinene. It has antiphytoviral activity against TMV, Cucumber Mosaic Virus (CMV), Tobacco Necrosis Virus (TNV), etc. The presence of low content of plant protein exhibits antimicrobial and antiviral activities [7].

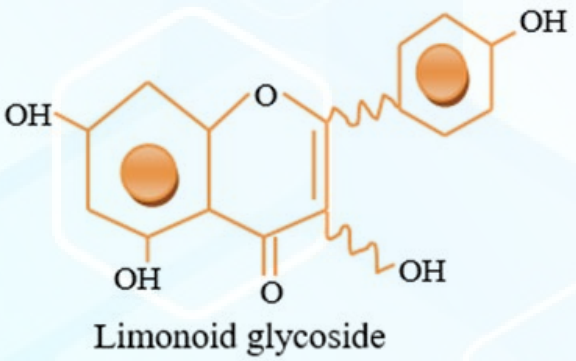

Figure 1.2: Chemical construction of orange peel extract

Orange peel or citrus aurantium dulcis contains provitamin A, folate, riboflavin, thiamine, vitamin B6 and calcium. It also has D-limonene (73.9-97%), which shows antimicrobial properties against *Staphylococcus aureus, Listeria monocytes* and *Pseudomonas aeruginosa*) [8].

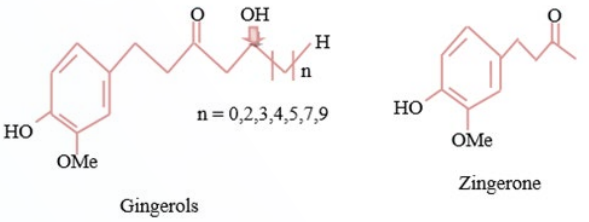

Figure 1.3: Chemical construction of ginger peel extract

Ginger peel or zingiber officinale roscoe, which belongs to the Zingiberaceae family and *Zingiber* genus, contains more polyphenols than the flesh, oleoresin, oxymethyl phenols, zingerone and gingerol. It is used for its anti-bacterial, anti-flatulent, antimicrobial, anti-inflammatory, antiseptic, anti-spasm, anti-viral and anti-oxidative properties [9].

The usage of biodegradable and environment friendly materials helps to achieve the objective of building a sustainable world. This subject was chosen to create an upcycled product as well as to create a textile-related natural shield of defence. These products were chosen because they may be found all year round and are frequently used. Therefore, these wastes can be continuously collected. So, employing them as antimicrobial agents will be beneficial for waste management.

2. Materials and methods

2.1. Fabric preparation

100% cotton single jersey knitted fabric with 174 GSM was used for antimicrobial finishing. It was collected from Primeasia University knitting lab and further processing was done in wet processing lab. It was pretreated, such as desizing and scouring were done to increase the exhaustion rate of the finishing agent. The traditional scouring was done with 2% NaOH, 1% Na_2CO_3 and 3 gm/L non-ionic emulsifiers at 80°C for 2 hrs [10]. The finishing was done on a dyed sample to observe the effect of the natural antimicrobial agents on the fabric after dyeing. It was dyed with red-colored reactive dyes.

2.2. Antimicrobial agent preparation

The food wastes used for the antimicrobial property of the cotton knitted fabric are; lemon peel *(Citrus limon)*, orange peel *(Citrus Aurantium Dulcis)* and ginger peel *(Zingiber officinale)*. These are collected for a few days, then sundried until the peels become crispy. After sun drying, the peels are separately ground in fine powder. These powders are taken in 5% amounts and soaked into ethanol (99.9% Ethanol absolute) overnight [11]. The ingredients were soaked in ethanol to activate the natural substances. This was done in Wet Process lab of Primeasia University.

Table 2.1: Samples treated with different ingredients

Sample description	Amount
Sample-1: Lemon peel	5%
Sample-2: Orange peel	5%
Sample-3: Ginger peel	5%

2.3. Application process

The antimicrobial finish was done in an exhaust bath. The liquor ratio was 1:30, 8% citric acid was added to the bath as a binder to bind the natural finishing agents with the cotton fabric and the food waste-ethanol solution was added. After that, the fabric sample was added to the exhaust bath. It was kept like this for 30 minutes at 90°C with constant stirring. The samples were removed from the bath after 30 minutes and dried at 70°C until it was fully dried.

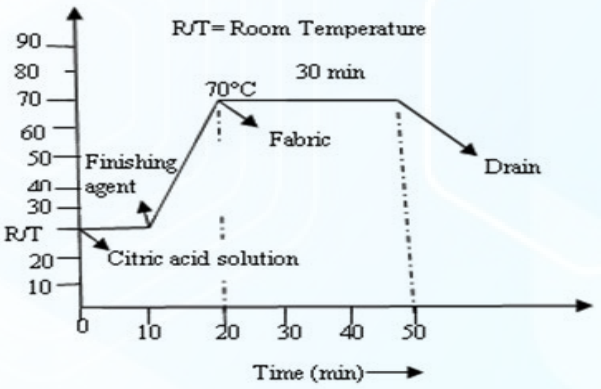

Figure 2.1: Antimicrobial finish application process

2.5. Antimicrobial test

There are two organisms used for testing the antimicrobial property of the finished sample. *Staphylococcus aureus* and *Escherichia coli* bacteria were used to test the samples. The presence of microorganisms on or around the finished sample was detected by minimum inhibitory concentration. Test bacteria were activated with the use of 1 ml of inoculums into 4 ml of Nutrient Broth at 37°C for 18-22 hours in the incubator. Serial dilution test organisms *(S. aureus & E. coli)* that grew in 1 day were in 1x10-7 MIC (minimum inhibitory concentration). The minimum zone of inhibition was assessed in the disc diffusion method. The inoculums were equally coated on a sterile nutrient agar plate and the finished fabric was placed on the disc and was inhibited at 37°C for 24 hrs. Later evaluation of the susceptibility of the test organism will be performed. The tests were performed in Microbiology lab of Primeasia University [12].

2.6. The durability of finish to washing

The durability of natural finishing agents washing was investigated by washing the finished sample repeatedly. It was washed using 2 g/L neutral detergents and washed for 30 minutes at 50±2°C temperature and it was counted as one cycle. After each cycle fabric was washed with cold water shaded dried and again washed. The natural antimicrobial finish treated samples were washed for 3 and 5 wash cycles and further tested to see the difference in their antimicrobial properties [12].

2.7. GSM of the fabric

The GSM or the weight per square meter area of the untreated sample was measured by a GSM cutter. The area of the GSM cutter was 1/100 m^2. The treated samples were cut into a square centimetre area and weighed in an electric balance. The weighing was done under

a standard atmosphere. Later calculated using the equation given below,

$$GSM = \frac{\text{Weight of sample in grams}}{\text{Area of sample in square cm}} \times 100$$

2.7. Flowchart

Figure 2.2: Process flowchart of the antimicrobial finish.

3. Results

After treated with food wastage there is a significant change in fabric GSM which is shown in table 3.1.

Table 3.1: Variation of GSM in before and after treated fabric

Sample type	GSM
Dyed untreated sample	174
Lemon peel-treated sample	194
Orange peel-treated sample	218
Ginger peel-treated sample	199

The findings of the antibacterial activity are shown in table 3.2. For this project, orange peel, lemon peel and ginger peel were used to create three distinct types of treated cloth from food waste. *Staphylococcus aureus*, a gram-positive microbe and *Escherichia coli*, a gram-negative pathogen, have both been tested against the cloth.

Sizes of inhibitory zones for *Escherichia coli* (Figure 3.1) *and Staphylococcus aureus* (Figure 3.2) microorganisms are shown.

Table 3.2: Inhibitory diameter (mm) of treated fabric in Escherichia coli and Staphylococcus aureus bacteria before treatment, after treatment, after 2 washes and after 5 washes.

Sample identification	Types of Treatment	Condition	*Escherichia coli*	*aureus*
	Sample treated with lemon peel	Before treatment	0	0
1		After treatment	15.24 ± 0.4	14.24 ± 0.4
2		After 2 washes	10.12 ± 0.4	13.19 ± 0.4
3		After 5 washes	0	0
	Sample treated with orange peel	Before treatment	0	
4		After treatment	18.04 ± 0.4	13.20 ± 0.4
5		After 2 washes	12.42 ± 0.4	11.96 ± 0.4
6		After 5 washes	0	0
	Sample treated with ginger peel	Before treatment	0	0
7		After treatment	14.9 ± 0.4	12.5
8		After 2 washes	12.16 ± 0.4	10.04 ± 0.4
9		After 5 washes	0	0

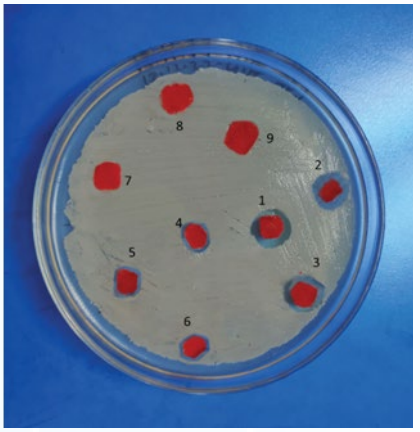

Figure 3.1: Inhibitory zone of treated fabric in Escherichia coli (gram-negative bacteria).

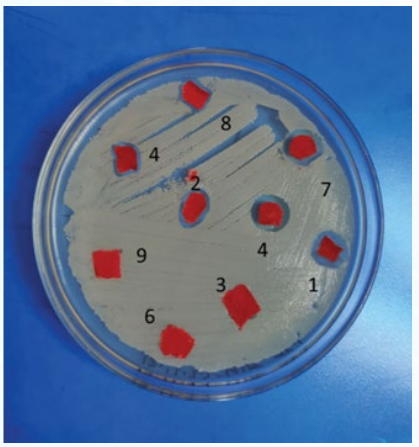

Figure 3.2: Inhibitory zone of treated fabric in Staphylococcus aureus (gram-positive bacteria).

4. Discussion

After analyzing table 3.1 it is revealed that antimicrobial treatment increase GSM of the fabric as a layer of antimicrobial agent has established in the fabric surface.

Results presented in table 3.2 show that the effectiveness of the treated fabric for gram-negative *Escherichia coli* bacteria is in order of orange > lemon> ginger. For gram-positive *Staphylococcus aureus* bacteria, the order of effectiveness is lemon> orange> ginger. The highest inhibitory zone is found in orange peel-treated fabric against *Escherichia coli* bacteria at 18.04 ± 0.4 mm. Washing reduces the inhibitory zone for all treated fabrics [13] and after 5 washes, the zone is no longer detectable.

Gram-negative bacteria are more sensitive than gram-positive bacteria. Gram-negative bacteria have a single layer of peptidoglycan and do not contain teichoic acid. On the other hand, gram-positive bacteria contain teichoic acid and has multilayer peptidoglycan cell on the outer layer [14, 15] All the selected treated fabric is more resistant to Escherichia coli bacteria than *Staphylococcus aureus*. The overall result of antibacterial properties is found better against *Escherichia coli* than *Staphylococcus aureus.*

Lemon-treated fabric shows an inhibitory zone of 15.24 ± 0.4mm in *Escherichia coli* but in *Staphylococcus aureus* bacteria inhibitory zone is a little bit lower. The structure of lemon peel can be the reason for this [16]. The drying mechanism of the orange peel may affect its antimicrobial activity [17].

In *Escherichia coli* bacteria orange peel gives the highest inhibitory zone which is 18.04 ± 0.4 mm. Orange peel shows a good inhibitory zone in both aqueous extract and alcoholic extract which confirms its antimicrobial activity [18]. Many studies have been done which confirm the better antibacterial activity of orange peel-treated fabric against *Escherichia coli* bacteria [19]. Ginger-treated dyed fabric shows more antibacterial properties against *Escherichia coli* than *Staphylococcus aureus.* Many similar studies have been done to show the microbial activity of ginger [9, 20, 21]. However ginger lost its microbial activity at boiling temperature against many bacteria [22]. With the decrease in ginger concentration diameter of the inhibitory zone also decreases [23].

There are several limitations to this research. Apart from durability and GSM test, the treated fabrics can be tested for several other tests to identify the practicality of using this finish commercially. Bursting tests, anti-static and water-repellency tests are a few of those.

5. Conclusion

The lemon peel shows antiphytoviral activity, orange peel shows antimicrobial properties and ginger peel or *Zingiber officinale Roscoe* is used for its anti-bacterial, anti-flatulent, antimicrobial, anti-inflammatory, antiseptic, anti-spasm, anti-viral and anti-oxidative properties. These can be used to impart nondurable antimicrobial properties on fabrics as after 5 washes none of these extracts showed any antimicrobial properties. However, each of the extracts showed variance in creating an inhibition zone in *Escherichia coli & Staphylococcus aureus* medium. Where lemon peel showed the most resistance among these three to *S. aureus* it showed somewhat mid-range

resistance for *E. coli.* Similarly, the orange peel had more effectiveness in *E. coli* and a medium effect in S. aureus. In both cases, ginger peel shows the least resistance to microbes comparatively. From GSM test of before and after treated fabric it can be deduced that lemon orange peel-treated fabric absorbs a larger amount of finish than the other two. As this work has limitations, the authors wish to work more on this topic to address those.

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Conflict of interest

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References

[1] J. Saha, S. Shankar Chakraborty, C. Author, A. Rahman, R. Sakif and A. Professor, "Antimicrobial Activity of Textiles from Different Natural Resources," 2021. [Online]. Available: www.questjournals.org

[2] M. Joshi, R. Purwar, S. Wazed Ali and S. Rajendran, "Antimicrobial Textiles for Health and Hygiene Applications Based on Eco-Friendly Natural Products," in Medical and Healthcare Textiles, Elsevier Ltd, 2010, pp. 84–92. doi: 10.1533/9780857090348.84.

[3] M. Joshi, W. Ali and & R. Purwar, "Ecofriendly antimicrobial finishing of textiles using bioactive agents based on natural products," 2009.

[4] D. Radhika, "Review Study on Antimicrobial Finishes on Textiles-Plant Extracts and Their Application," Int. Res. J. Eng. Technol., 2019, [Online]. Available: www.irjet.net.

[5] J. Singh, K. Sung, T. Cooper, K. West and O. Mont, "Challenges and opportunities for scaling up upcycling businesses – The case of textile and wood upcycling businesses in the UK," Resour. Conserv. Recycl., vol. 150, no. December 2018, p. 104439, 2019, doi: 10.1016/j.resconrec.2019.104439.

[6] M. D. TELI, S. P. VALIA, S. MAURYA and P. SHITOLE, "Sustainability Based Upcycling and Value Addition of Textile Apparels," Int. J. Appl. Phys. Sci., vol. 1, no. 3, pp. 41–47, 2015, doi: 10.20469/ijaps.50002-3.

[7] Y. Shan, "Extraction Processes of Functional Components From Citrus Peel," Compr. Util. Citrus By-Products, pp. 31–58, 2016, doi: 10.1016/b978-0-12-809785-4.00003-4.

[8] A. Geraci, V. Di Stefano, E. Di Martino, D. Schillaci and R. Schicchi, "Essential oil components of orange peels and antimicrobial activity," Nat. Prod. Res., vol. 31, no. 6, pp. 653–659, 2017, doi: 10.1080/14786419.2016.1219860.

[9] Mbaeyi Nwaoha, E. I, Okafor, I. Gabriel, Apochi and V. O, "Production of oleoresin from ginger (Zingiber officinale) peels and evaluation of its antimicrobial and antioxidative properties," African J. Microbiol. Res., vol. 7, no. 42, pp. 4981–4989, 2013, doi: 10.5897/ajmr2013.6125.

[10] A. Preet, P. Jaswal and G. Goel, "Antimicrobial activity of herbal treated cotton fabric," Int. Res. J. Eng. Technol., 2017, [Online]. Available: www.irjet.net

[11] C. Jennifer and D. K. Sangeetha, A Comparative study on Antimicrobial Finish using Pisidium Guajava leaf Extraction on Cotton, Organic Cotton and Bamboo Fabrics. 2016. [Online]. Available: www.ASDF.international]

[12] S. Yadav, N. M. Rose, S. Devi and A. Kumar, "Development of antibacterial finish for cotton with neem leaves extract and assessment of wash durability," J. Cott. Res. Dev, vol. 34, no. 1, pp. 158–166, 2020.

[13] M. Zayed, H. Ghazal, H. A. Othman and A. G. Hassabo, "Synthesis of different nanometals using Citrus Sinensis peel (orange peel) waste extraction for valuable functionalization of cotton fabric," Chem. Pap., vol. 76, no. 2, pp. 639–660, 2022, doi: 10.1007/s11696-021-01881-8.

[14] P. H. Moreno, F. da Costa-Issa, A. Rajca-Ferreira, M. Pereira and T. Kaneko, "Native Brazilian Plants Against Nosocomial Infections: A Critical Review on their Potential and the Antimicrobial Methodology," Curr. Top. Med. Chem., vol. 13, no. 24, pp. 3040–3078, 2013, doi: 10.2174/15680266113136660219.

[15] K. Samarakoon et al., "Antibacterial effect of citrus press-cakes dried by high speed and far-infrared radiation drying methods," Nutr. Res. Pract., vol. 6, no. 3, pp. 187–194, 2012, doi: 10.4162/nrp.2012.6.3.187.

[16] M. Saleem and M. T. Saeed, "Potential application of waste fruit peels (orange, yellow lemon and banana) as wide range natural antimicrobial agent," J. King Saud Univ. - Sci., vol. 32, no. 1, pp. 805–810, 2020, doi: 10.1016/j.jksus.2019.02.013.

[17] R. Farahmandfar, B. Tirgarian, B. Dehghan and A. Nemati, "Comparison of different drying methods on bitter orange (Citrus aurantium L.) peel waste: changes in physical (density and color) and essential oil (yield, composition, antioxidant and antibacterial) properties of powders," J. Food Meas. Charact., vol. 14, no. 2, pp. 862–875, 2020, doi: 10.1007/s11694-019-00334-x.

[18] D. Gao, X. Li, Y. Li, B. Lyu, J. Ren and J. Ma, "Long-acting antibacterial activity on the cotton fabric," Cellulose, vol. 28, no. 3, pp. 1221–1240, 2021, doi: 10.1007/s10570-020-03560-5.

[19] M. G. Shehata, T. S. Awad, D. Asker, S. A. El Sohaimy, N. M. Abd El- Aziz and M. M. Youssef, "Antioxidant and antimicrobial activities and UPLC-ESI-MS/MS polyphenolic profile of sweet orange peel extracts," Curr. Res. Food Sci., vol. 4, no. December 2020, pp. 326–335, 2021, doi: 10.1016/j.crfs.2021.05.001.

[20] J. J. Yang and F. Rahmawati, "Antimicrobial effects of various red ginger (Zingiber officinale) extract concentrations on Escherichia coli bacteria," vol. 10, no. 2, pp. 63–67, 2022.

[21] A. Kimbonguila, L. Matos, J. Petit, J. Scher and J.-M. Nzikou, "Effect of Physical Treatment on the Physicochemical, Rheological and Functional Properties of Yam Meal of the Cultivar 'Ngumvu' From Dioscorea Alata L. of Congo," Int. J. Recent Sci. Res., vol. 10, no. April, pp. 30693–30695, 2019, doi: 10.24327/IJRSR.

[22] S. Pankaj, A. T. Balqees, A. N. Najat and A. M. Rahma, "Effect of temperature on antibiotic properties of garlic (Allium sativum L.) and ginger (Zingiber officinale Rosc.)," African J. Biotechnol., vol. 11, no. 95, pp. 16192–16195, 2012, doi: 10.5897/ajb12.1402.

[23] R. Sikrodia, D. Chhabra, S. D. Audarya and R. Sharda, "Efficacy of Antimicrobial Activity of Aqueous Extract of Garlic (Allium sativum) and Ginger (Zingiber officinale) against Different Bacterial Species," Int. J. Curr. Microbiol. Appl. Sci., vol. 7, no. 09, pp. 3021–3025, 2018, doi: 10.20546/ijcmas.2018.709.376.